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# Prosthodontics at the Threshold of Intelligence

Prosthodontics has long evolved through incremental refinements in materials, techniques, and technology. The integration of digital workflows marked a significant transition by improving precision, efficiency, and standardization. As the specialty advances further, it now stands at the threshold of a more profound transformation, one in which intelligence, rather than digitization alone, begins to shape prosthodontic care.

Contemporary digital Prosthodontics primarily focuses on converting analog procedures into virtual equivalents. While this transition has improved reproducibility and reduced technical variability, clinical decision making remains largely dependent on individual expertise. Emerging intelligent systems suggest a future in which Prosthodontic workflows extend beyond digital execution toward data informed clinical support.

Artificial Intelligence driven systems offer the potential to assist in identifying patterns that are difficult to perceive through conventional analysis alone. These may include trends in edentulous span behavior, prosthesis design variability, occlusal relationships, and long-term biomechanical performance. When applied responsibly, such systems could enhance consistency in diagnosis and planning, particularly in complex rehabilitative scenarios.

Another anticipated advancement lies in the convergence of diagnostic data streams. The integration of intraoral scanning, facial analysis, functional records, and historical treatment outcomes may allow prosthodontic planning to become increasingly predictive rather than reactive. Prostheses could be designed with consideration for anticipated biologic and functional changes, shifting emphasis from short-term fit to long-term performance.

Material science and manufacturing technologies are also progressing toward greater adaptability. Additive manufacturing continues to expand beyond provisional applications, and future developments may support prostheses that are more responsive to functional demands and oral environmental conditions. These advances may further narrow the distinction between laboratory based and chairside fabrication while maintaining prosthodontic quality standards.

As intelligent systems enter clinical workflows, the role of the Prosthodontist remains central. Clinical judgment, ethical responsibility, and patient centered care cannot be delegated to automated processes. Instead, the Prosthodontist will increasingly serve as the interpreter and regulator of intelligent outputs, ensuring that technological recommendations align with biologic principles and individual patient needs.

The future of Prosthodontics will not be defined by the sophistication of technology alone, but by how judiciously it is integrated into clinical reasoning. As the specialty continues to evolve, maintaining a balance between innovation and foundational Prosthodontic principles will be essential to ensure meaningful and sustainable advancement.

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# Contents



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# Orthodontic and Implant Rehabilitation of a Patient with Missing Mandibular Incisors:A Case Report

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## Abstract

**Introduction:** The loss of mandibular incisors, whether congenital or acquired, presents aesthetic, functional, and biomechanical challenges for orthodontists. Restoring anterior guidance, space balance, and smile esthetics and harmony often requires interdisciplinary planning with prosthetic rehabilitation.

**Case Report:** A 17-year-old female patient reported with a Class I molar and canine relationship. Clinical examination revealed microdontia of tooth 41 along with congenital absence of teeth 31 and 42. Overjet and overbite could not be assessed due to the absence of mandibular anterior teeth. Orthodontic treatment with a 0.022-in MBT fixed appliance system was initiated to redistribute space and align arches while maintaining molar and canine relationships. Sequential archwire progression (0.014-in NiTi to 0.019 × 0.025-in stainless steel) achieved proper space distribution. Therapeutic extraction of 41 was done and CBCT confirmed adequate alveolar bone. Two implants were placed in the 31 and 42 regions. Following osseointegration, screw-retained crowns were delivered. Retention was provided with a fixed mandibular canine-to-canine retainer and a removable maxillary retainer.

**Results:** Treatment achieved well-aligned arches with preservation of Class I relationships and ideal space for prosthetic rehabilitation. Implant supported crowns successfully restored aesthetics, phonetics, and function. At the 12-month follow-up, occlusion remained stable, with improved esthetics, function, and patient satisfaction.

**Discussion:** This case underscores the importance of orthodontic biomechanics in space creation and root positioning prior to implant placement. Literature supports that inter-disciplinary collaboration is essential for long-term stability and aesthetic success in cases of anterior tooth loss. Implant supported crowns offer a durable and aesthetic alternative compared with space closure or conventional prostheses.

**Conclusion:** An interdisciplinary orthodontic–prosthodontic approach is essential in managing patients with missing mandibular incisors. Sequential archwire therapy optimized space distribution and root parallelism, enabling successful implant placement and long-term aesthetic and functional outcomes.

**Keywords :** Class I malocclusion, mandibular incisor agenesis, implant supported restoration, interdisciplinary orthodontics

## Introduction

Loss or agenesis of mandibular incisors is uncommon compared with other missing teeth, yet it significantly affects aesthetics, phonetics, and function. Management requires careful consideration of space distribution, occlusal stability, and long-term restorative planning. Orthodontic treatment can optimize space and alignment, while implant supported restorations offer functional and esthetic replacement once growth is complete. This report presents the Inter-disciplinary management of a patient with missing mandibular incisors using fixed orthodontic therapy followed by implant rehabilitation.

## Case Report

### Diagnosis and Etiology

A 17-year-old female presented with the chief complaint of spacing and aesthetic concerns in the lower anterior region. Clinical

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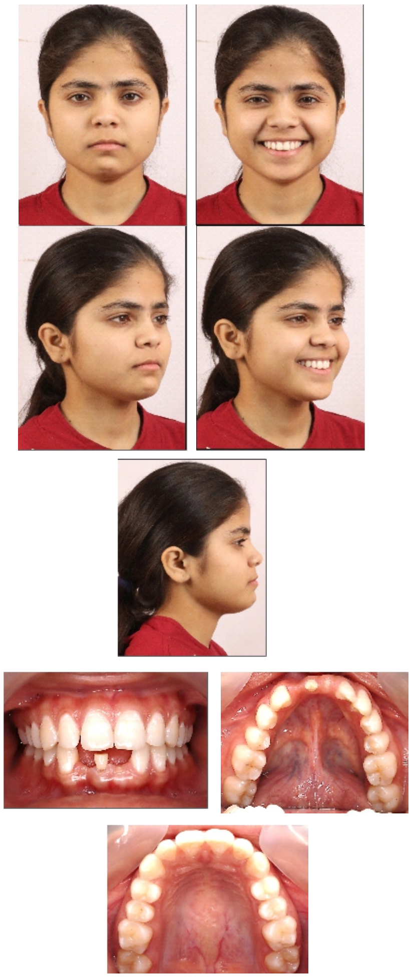
and radiographic examination revealed :



Pretreatment Intraoral and Extraoral

1. Microdontia of tooth 41 along with
2. Congenital absence of teeth 31 and 42
3. Bilateral Class I molar and canine relationship
4. Maxillary arch well aligned; mandibular arch with anterior spacing
5. Overjet and overbite could not be assessed due to the absence of mandibular incisors
6. Favorable periodontal health and adequate alveolar bone in the edentulous region
7. The diagnosis was Angle's Class I malocclusion with missing mandibular central and lateral incisors.

## Treatment Objectives

1. Maintain Class I molar and canine relation.
2. Align and level both arches with ideal space distribution.
3. Provide adequate space for replacement of 31, 41, and 42.
4. Restore aesthetics and function through implant-supported prostheses.

## Treatment Alternatives

**Three Alternatives were Considered**

1. Space closure orthodontically with canine substitution rejected due to aesthetic compromise and functional discrepancy.
2. Resin bonded fixed prosthesis not favoured due to reduced long-term predictability.
3. Implant supported restoration after orthodontic space management selected as the most conservative and stable approach.

## Treatment Progress

Treatment Progress

Fixed appliance therapy was initiated using a 0.022 in slot MBT prescription preadjusted edgewise appliance system in both arches. The Maxillary arch was bonded for stabilization, while the mandibular arch was bonded to redistribute space in the anterior region and to maintain arch form

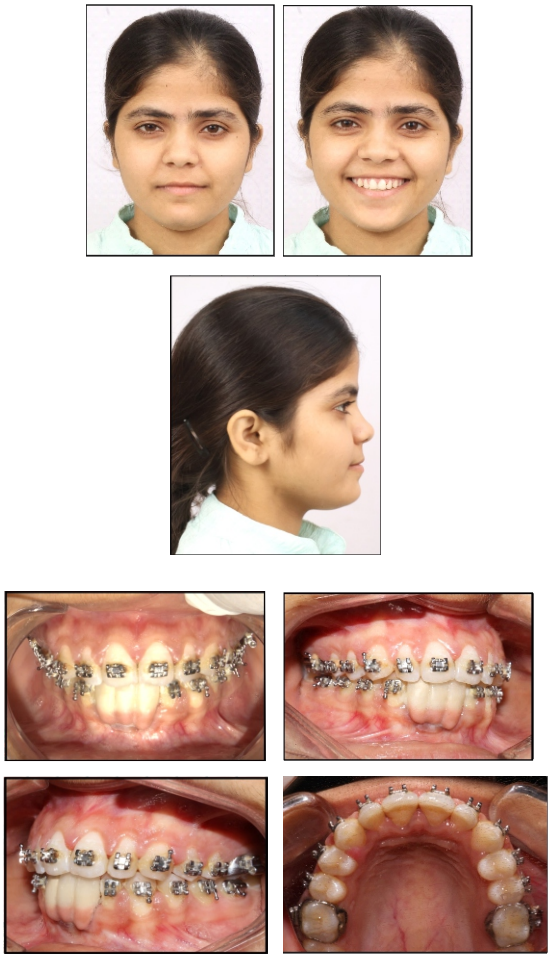
1. **Extraction:** Extraction of microdontia teeth 41
2. **Alignment and levelling:** Initial alignment was achieved with 0.014-in NiTi archwires, progressing sequentially through 0.016-in NiTi and 0.018-in NiTi to correct minor rotations and establish proper levelling.
3. **Working Phase:** Progression to rectangular wires (0.017 × 0.025-in NiTi followed by 0.019 × 0.025-in stainless steel) allowed torque expression and arch coordination. During this stage, particular emphasis was placed on space distribution in the mandibular anterior region. Light inter-arch elastics were used selectively to maintain intermaxillary coordination without altering the established Class I molar and canine relation.
4. **Space Management:** Careful monitoring ensured that the space created corresponded to the mesiodistal width of three mandibular incisors. Bolton's analysis and diagnostic wax-up guided space distribution.
5. **Finishing:** Finishing and detailing were carried out with 0.019 × 0.025-in TMA archwires, incorporating minor bends to refine incisor angulation and to establish optimal intercuspation. Settling elastics were used to improve posterior occlusion.

After debonding, CBCT scan was performed to confirm bone availability and root parallelism in the mandibular anterior region. This ensured an adequate foundation for implant placement without encroaching on adjacent root structures.

Three endosseous implants were placed in positions corresponding to 31 and 42. A healing period of 4 months was allowed for osseointegration, after which screw retained implant supported crowns were fabricated and delivered. Final occlusion showed ideal space restoration, maintenance of Class I molar and canine relation, and proper alignment of arches.

Retention was achieved using a fixed bonded retainer in the mandibular anterior region (canine to canine)to preserve alignment and a maxillary removable retainer to maintain transverse stability.

## Results



Result Post Treatment Introral and Extraoral

1. Class I molar and canine relation maintained.
2. Ideal space distribution in the mandibular anterior segment.
3. Implant supported crowns provided excellent aesthetics, phonetics, and functional occlusion.
4. Patient reported significant improvement in smile aesthetics and confidence.

## Discussion

The management of patients with missing mandibular incisors presents unique challenges in orthodontics and restorative dentistry. The absence of these teeth affects anterior guidance, phonetics, aesthetics, and smile harmony. Orthodontic treatment must be carefully coordinated with prosthodontic planning to achieve both functional and aesthetic rehabilitation.

1. **Biomechanical Considerations:** Maintaining the Class I molar and canine relationship was crucial, as altering the antero-posterior occlusion would have compromised function. The use of a sequential archwire system allowed for gentle alignment, space distribution, and torque control, minimizing risks of root resorption and periodontal compromise. Rectangular stainless steel archwires provided stability during space maintenance, ensuring that adequate and symmetrical space was preserved for implant placement.
2. **Interdisciplinary Planning:** The decision to restore the missing teeth with implants was based on the patient's age, periodontal health, and sufficient alveolar bone volume. Implant supported crowns provide a fixed, aesthetics, and functionally stable solution compared with removable or resin bonded prostheses, which are often less durable and aesthetically inferior in the long term. The timing of implant placement was critical post-growth completion to ensure long-term stability and to prevent Infraocclusion.
3. **Literature Support:** Kokich (2004) emphasized that orthodontic space management prior to implant placement is essential for ideal restorative outcomes, as improper space distribution may lead to compromised aesthetics or difficulty in implant placement. Proffit et al. (2018) described the importance of interdisciplinary collaboration in such cases, underscoring that implants should only be placed once growth has ceased to avoid occlusal discrepancies. Several clinical reports have demonstrated predictable aesthetic and functi-onal outcomes when orthodontics is combined with implant-based rehabilitation in cases of anterior tooth agenesis or traumatic loss.
4. **Clinical Significance:** This case underscores the importance of interdisciplinary collaboration. Orthodontics alone could not have restored the patient's aesthetics and function, but it created the foundation for implant placement by aligning adjacent teeth and ensuring adequate root angulation and space. The final result demonstrates that combining orthodontic biomechanics with implant prosthodontics can achieve long-term occlusal stability, aesthetics, and patient satisfaction.

## Conclusion

This case demonstrates that successful management of patients with missing mandibular incisors requires a coordinated orthodontic prosthodontic approach. Orthodontic treatment played a critical role in redistributing and maintaining space, controlling root angulation, and preserving the existing Class I molar and canine relationships. Sequential archwire mechanics allowed for gentle alignment and space preparation, ensuring a biologically sound foundation for implant placement. The subsequent placement of three mandibular implants provided a definitive, aesthetic and functional replacement for the missing teeth, restoring anterior guidance, phonetics, and smile aesthetics.

The outcome highlights several clinical principles:

1. Space creation and root positioning must be orthodontically optimized before implant placement.
2. Interdisciplinary treatment planning between orthodontist and prosthodontist is indispensable to achieve harmonious aesthetic and functional results.
3. Implant Supported prostheses represent a stable, long-term solution for anterior tooth loss in young adults once skeletal growth has ceased.

Overall, the integration of orthodontic biomechanics with implant prosthodontics can achieve predictable and stable results, significantly improving oral function, smile aesthetics and patient satisfaction.

## References


1. Argyropoulos E, Payne G. Techniques for improving orthodontic results in the treatment of missing maxillary lateral incisors: a case report with literature review. Am J Orthod Dentofacial Orthop. 1988 Aug; 94 (2) :150–65.
2. Riedel RA, Little RM, Bui TD. Mandibular incisor extraction postretention evaluation of stability and relapse. Angle Orthod. 1992; 62 (2) :103–16.
3. Valinoti JR. Mandibular incisor extraction therapy. Am J Orthod Dentofacial Orthop. 1994;105(2):107–16.
4. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod. 1997; 31 (11): 763–67.
5. Klein DJ. The mandibular central incisor, an extraction option. Am J Orthod Dentofacial Orthop. 1997; 111 (3): 253–9.
6. Newman GV, Newman RA. Report of four familial cases with congenitally missing mandibular incisors. Am J Orthod Dentofacial Orthop. 1998 Aug;114 (2) :195–207.
7. Robertsson S, Mohlin B. The congenitally missing upper lateral incisor. A retrospective study of orthodontic space closure versus restorative treatment. Eur J Orthod. 2000; 22 (6): 697–710.
8. Thilander B, Odman J, Lekholm U. Orthodontic aspects of the use of oral implants in adolescents: a 10 year follow-up study. Eur J Orthod. 2001;23: 715–31.
9. Bernard JP, Schatz JP, Christou P, Belser U, Kiliaridis S. Long-term vertical changes of the anterior maxillary teeth adjacent to single implants in young and mature adults. J Clin Periodontol. 2004; 31:1024–28.
10. Kokich VG. Managing orthodontic-restorative treatment for the adolescent patient. Am J Orthod Dentofacial Orthop. 2004; 125 (6): 603–9.
11. Thind BS, Stirrups DR, Forgie AH, Larmour CJ, Mossey PA. Management of hypodontia: orthodontic considerations (II). Quintessence Int. 2005; 36 (5): 345–53.
12. Kokich VO, Kinzer GA. Managing congenitally missing lateral incisors. Part I: Canine substitution. J EsthetRestor Dent. 2005; 17 (1): 5–10.
13. Kokich VO, Kinzer GA. Managing congenitally missing lateral incisors. Part II: Tooth supported restorations. J EsthetRestor Dent. 2005;17 (2): 76–84.
14. Kokich VG, Kokich VO, Spear FM. Interdisciplinary management of anterior dental esthetics. J Am Dent Assoc. 2006;137 (2):160–9.
15. Endo T, Ozoe R, Kojima K, Shimooka S. Congenitally missing mandibular incisors and mandibular symphysis morphology. Angle Orthod. 2007 Nov; 77 (6) :1079–84.
16. Thilander B. Orthodontic space closure versus implant placement in subjects with missing teeth. J Oral Rehabil. 2008;35 Suppl 1:64–71.
17. Ikeda H, Rossouw PE, Campbell PM, Kontogirogos E, Buschang PH. Three dimensional analysis of peri-bone-implant contact of rough surface miniscrew implants. Am J Orthod Dentofacial Orthop. 2011;139 (2): e153–63.
18. Zhylich D, Suri S. Mandibular incisor extraction: a systematic review of an uncommon extraction choice in orthodontic treatment. J Orthod. 2011; 38 (3):185–95.
19. Oliveira DD, de Oliveira BF, da Mata Cid Pinto LS, Figueiredo DS, Pithon MM, Seraidarian PI. Interdisciplinary treatment of a class III patient with congenitally absent maxillary lateral incisors. J EsthetRestor Dent. 2013 Aug; 25 (4): 242–53.
20. Germec-Cakan D, Canter HI, Cakan U, Demir B. Interdisciplinary treatment of a patient with bilateral cleft lip and palate and congenitally missing and transposed teeth. Am J Orthod Dentofacial Orthop. 2014 Mar; 145 (3): 381–92.
21. Almeida RR, Morandini AC, Almeida-Pedrin RR, Almeida MR, Castro RC, Insabralde NM. A multidisciplinary treatment of congenitally missing maxillary lateral incisors: a 14-year follow-up case report. J Appl Oral Sci. 2014 Sep-Oct; 22 (5): 465–71.
22. Proffit WR, Fields HW, Larson BE, Sarver DM. Contemporary Orthodontics. 6th ed. St. Louis: Elsevier; 2018.
23. Hwang S, Kim I, Jang W, Choi YJ, Chung CJ, Kim KH. A 15-year follow-up of an orthodontic treatment including a lower incisor extraction and keeping the maxillary canine-premolar transposition. Angle Orthod. 2019; 89 (5): 812–26.
24. Priestly G. The treatment dilemma of missing maxillary lateral incisors Part II : Implant restoration. J EsthetRestor Dent. 2019 Jul; 31(4): 319–26.
25. Paduano S, Barbara L, Aiello D, Pellegrino M, Festa F. Clinical management of hypodontia of two mandibular incisors. Case Rep Dent. 2021 Feb 3; 2021: 6625270.

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# Palatal Morphology and Its Relative Effect on Malocclusion A Review

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## Abstract

Craniofacial structures, including the human palate, exhibit unique morphological variations. Palatal morphology influences malocclusion and is affected by factors such as breathing, tongue posture, and dental habits. This review explores literature on palatal morphology, focusing on arch form, length, depth, and rugae patterns, and their impact on dentoalveolar and skeletal patterns. A four-month search identified relevant studies from PubMed, Web of Science, Scopus, and Google Scholar, with fifteen articles selected for analysis. Findings indicate significant variations in palatal morphology across malocclusion classes and skeletal growth patterns. Class I malocclusions have larger maxillary bases and intermolar widths compared to Class II and III. Class II division 1 malocclusions show greater palatal height and narrower maxillary arches, while Class II division 2 exhibits wider arches and lower palatal heights. Unique and stable palatal rugae serve as reliable identification markers in forensic medicine. Advances in imaging techniques have enhanced understanding, aiding in diagnosis and tailored treatments.

**Keywords -** Palatal Morphology, Malocclusion, Skeletal Growth Pattern.

## Introduction

Each person is born with unique craniofacial structures, formulations, and facial characteristics that distinguish them from others.[1] The human palate, with its complex morphology and functional importance, is crucial for speech articulation and maintaining occlusal harmony. Palatal morphology, characterized by its shape, size, and structural variations, has long been implicated in the etiology of malocclusion a complex dental anomaly affecting millions worldwide. Many factors, including breathing pattern, tongue posture and size, dental inclination, occlusion, and parafunctional behaviours, have influence on its irregular form[2].

Malocclusions in three dimensions (3D) often occur at the same time and usually interrelate with each other. Growth follows the sequential completion of the cranium followed by facial width (transverse), then facial depth (sagittal), and finally facial height (vertical). Transverse growth highlights dentofacial asymmetries, jaw expansion or constriction, and dental crossbites. Sagittal growth provides insights into facial profiles, arch length discrepancies, and overjet issues. Vertical growth patterns reveal facial proportions, deep bites, and open bites.

Transverse growth is nearly complete by late adolescence, whereas sagittal and vertical growth continue well into adulthood. Therefore, a lack of maxillary transverse width will affect the vertical and sagittal development of maxillofacial bone in the early stages, which is hard to perceive. Malocclusion usually occurs in mixed dentition or permanent dentition when the transverse development approaches completion. For this situation, patients usually did not

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report the insufficient transverse width but the sagittal problem as their main complaint, so clinicians were often more likely to pay attention to the sagittal dimension[3]. However, more recently, the contributions of maxillary expansion have become well known among dental professionals. When deciding between non extraction with maxillary expansion and extraction treatments in borderline patients, clinicians should carefully diagnose and select a plan based on the patient's maxillary width.

This review article aims to provide an comprehensive overview of the current literature pertaining to palate morphology such as the arch form, length, depth, the rugae patterns, and its effects on dentoalveolar and skeletal patterns.

## Methods

Research publications were searched for 4-months on PubMed, Web of Science, Scopus, and Google Scholar and the articles with the terms palatal morphology, palatal vault, arch form and malocclusions were collected. Furthermore, all the articles were analyzed to determine the relationship between palatal morphology and malocclusion.

## Results

Finally, Fifteen relevant articles were selected to formulate this review.

## Discussion

### Palatal Morphology

The hard palate, a bone wall that separates the mouth and nasal cavities, acts both the oral cavity's roof and the nasal cavity's bottom. The palatal processes of the maxillary bones make up the front section of the hard palate, whereas the horizontal plates of the palatal bones create the posterior (distal) section. The shape of the palatal vault shows great variability.[4]

Palate expansion mainly occurs during the first 5 years of life at the intermaxillary and interpalatine sutures. Later, width increases are due to bone growth on the outer surfaces of the maxillary bones and the eruption of permanent teeth, resulting in up to a 2.2 mm increase in intermolar width. These changes are associated with the vertical growth of the alveolar process, which diverges to form the palatal walls. A narrow or triangular palate often indicates an abnormal tongue position, as the tongue rests on the floor of the mouth instead of the palatal rugae, exerting pressure on the teeth. A low tongue position may lead to lower dental arch expansion and upper arch collapse.[5]

In primary dentition, Hughes et al (2001) found that genetic factors significantly influence variation in maxillary arch width; Eguchi et al (2004) found that there is significant additive genetic variance in maxillary arch width, depth, and palatal height in teenage twins. Palate growth is influenced by both genetic and environmental factors, determined by a complex interaction of factors including developmental timing, soft tissue influences, and growth peak period.[6]

According to Harvold et al., the shape of the maxillary arch is largely influenced by tongue posture and movements, particularly during key stages of dental development such as the complete eruption of the maxillary first molars. In children undergoing growth, local factors like muscle recruitment and respiratory patterns, as well as genetic factors affecting cell responsiveness, influence palatal vault development. Similarly, Lione et al. found that mouth breathing during growth led to distinct palatal morphology, characterized by a narrower and higher vault compared to nose breathing individuals.[7]

Palatal rugae, unique crests similar to fingerprints, are located on either side of the palatine raphe past the incisive papilla. They remain stable despite tooth changes, making them ideal for analysis. Typically numbering three to five per side, they do not extend past the anterior half of the hard palate or cross the midline. An increased size of palatal rugae has been linked to the presence of an open bite.[8] Thomas (1983) observed that palatal rugae remain unchanged except in length, likely due to underlying growth. Comparative studies across diverse Indian populations, including Karnataka, Kerala, and Manipur, revealed significant differences in rugae patterns. M Selvamani et al. found that females from Kerala had a greater number of primary rugae compared to males.[9]

## Relationship between Palatal Morphology and Malocclusion

Facial forms are one of the first parameters assessed by orthodontists during their initial extra-oral examination. The various types of facial forms as proposed by Martin (1957)[48] through facial indices are leptoprosopic, euryprosopic, and mesoprosopic. Individuals with these facial forms present with unique facial features and intraoral findings. Leptoprosopic individuals have deeper palatal arches, a tendency towards constricted basal arch forms and are more towards the hyperdivergent growth pattern. Euryprosopic individuals have shallower palatal arches with wider basal arch forms and have a more horizontal or hypodivergent growth pattern. (Christie, 1977)[10].

Parcha et al. (2017) explored the relationship between facial forms and palate depth in children and adolescents. They found that high angle cases tended to have higher and narrower palates, while low angle cases were associated with shallower and wider palates. Children generally had longer and shallower palates compared to adolescents, likely due to bone growth and palate remodeling.

Palatal depth assessment typically involves qualitative categorization as high, moderate, or shallow. In 1939, Korkhaus introduced a quantitative method the Korkhaus Palatal Index to measure palate depth and arch width reliably. Palates were classified as high (> 22 mm), moderate (19–22 mm), or shallow (< 19 mm) using this index. The palatometer was employed to measure depth, with the central fossa of 1st molars as a reference for arch width. The normal palatal index, calculated by dividing arch width by palate depth, is around 42%, aiding in identifying transverse arch width issues. Korkhaus Palatal Index was found to be significantly larger in Class II division 1 malocclusion 45.06 ± 4.94 (%) as compared to Class I malocclusion 42.58 ± 3.21 (%).One potential drawback of this method was that the inclination of the molars was not taken into consideration. Hence, it would not give a correct assessment of the arch width and values indicating either expansion or constriction[10]

Prasanna et al. (2020) conducted a CBCT retrospective study on hyperdivergent patients, aiming to correlate molar inclination with palatal depth and assess transverse discrepancies. They found a significant correlation between molar inclination and palatal depth in vertical growers ($P < 0.05$). Increased palatal depth corresponded to greater buccolingual inclination of first molars, suggesting increased buccal flaring and buccal root torque. This study aligns with Mitra and Ravi (2011)[10], who noted increased palatal inclination of molars in short faced individuals. Conversely, Janson et al. (2004)[10] suggested notable buccal inclination in maxillary second molars among long-faced individuals.

Palate depth, arch width, and molar inclinations guide treatment decisions. Assessing arch width, especially if it's mildly reduced (based on palatal index), alongside molar inclinations, informs whether tipping alone can correct transverse discrepancies or if more substantial expansion via devices like Hyrax or MARPE is needed. Southard et al. (2019)[11] differentiated dental and skeletal crossbites. Decompensating molar inclinations resolves dental crossbites positively but worsens skeletal ones. CBCT aids in assessing molar inclinations, identifying arch width, and confirming periodontal biotype, crucial for adults to avoid complications like fenestration and dehiscence due to excessive buccal crown torque[10].

Laganà et al.[12] utilized geometric morphometric analysis (GMM) to compare palatal shape variations between open bite and control subjects. Results revealed a marked constriction of the maxillary arch in open bite subjects compared to controls with normal occlusion. Interestingly, palatal shape variations in the open bite group were unaffected by non-nutritive sucking habits.

Huang X. et al studied palatal morphology in skeletal Class I and Class II subjects with retrusive mandibles. They found males had a generally higher and wider posterior palate than females, regardless of sagittal and vertical patterns. In skeletal Class II subjects, males with hyperdivergent and normodivergent patterns had a higher, narrower posterior palate, while females had a higher palate without significant narrowing compared to hypodivergent subjects. Overall, skeletal Class II subjects had a flatter, narrower posterior palate than Class I subjects. The study concluded that sagittal and vertical patterns significantly impact palatal morphology, with increased vertical dimensions linked to a higher, narrower palate[13]

Buschang P.H. et al (1994)[14] conducted a study on dental arch morphology, palatal height, and incisor irregularity in adult females. The study found that younger age groups had significantly larger maxillary and mandibular arches, while the oldest group had shorter and wider arches. Palatal height was greatest in the youngest and least in the oldest group. Class II subjects had smaller arches, greater maxillary incisor irregularity, and less mandibular incisor irregularity compared to Class I subjects. Additionally, Class II division 1 subjects had greater palatal heights and longer, narrower maxillary arches than Class II division 2 subjects.

There are also significant differences in arch size and shape between subjects with Class I and Class II malocclusion. The maxillary arch is significantly larger in Class I than in Class II malocclusion, females with Class II division 2 malocclusion have the smallest maxillary arches. The longer, narrower maxillary arches of Class II division 1 females suggest that posterior posturing of the mandible may be necessary to maintain occlusal contacts. Mandibular arch size is greatest for Class II division 1 patients, followed by Class I and Class II division 2, respectively. This result can be explained by the fact that the etiology of Class II malocclusion is related to mandibular retrognathism, maxillary prognathism, or a combination.[14]

Skeletal Class III malocclusion is characterized by maxillomandibular disharmony and a distinctive palatal shape compared to other skeletal patterns. Chen et al. studied the dental arches and skeletal bases in untreated Class III subjects, finding that the maxillary skeletal base and intermolar widths were significantly smaller in the Class III group compared to the Class I group, whereas mandibular intermolar widths did not differ significantly between the groups.[15] Lateral cephalograms are the standard for studying craniofacial morphology in Class III subjects. However, conventional cephalometry and dental cast analysis, relying on angular and linear measurements, are insufficient for analyzing complex anatomical shape changes.

Ahn et al.[15] analyzed CBCT and maxillary study models to investigate the relationship between palatal morphology and facial skeletal patterns in adult patients with Class III malocclusion. They found that increased transverse facial skeletal width was associated with narrow, deep, and long palates. Similarly, Paoloni et al.[15] observed in growing Class III malocclusion subjects that increases in angle divergence correlated with narrow and high palates, indicating a significant covariation between palatal and craniofacial morphology.

## Clinical Implications

Palatal morphology significantly influences an individual's skeletal and facial patterns and it can be influenced by orthodontic treatment. Hence, analysis of osseous or dental arch dimensions is fundamental in orthodontic treatment planning.

Currently, the need for palatal expansion treatment in mixed dentition is increasing. Early treatment with palatal expansion eliminates crossbites in an effort to guide normal occlusal development. Additionally, in patients with crowding, expansion increases space to avoid the need for extraction and jaw surgery in adult orthodontic treatments.[6] There are various types of expansion treatments available, but most result in the buccal inclination of the molars that leads to relapse. Lemos et al. (2018) compared two types of expanders, Haas-type and Hyrax-type, finding that the latter poses a higher risk of root and alveolar bone resorption due to molar force exertion. Clinical success has been reported using bone-borne palatal expanders with mini-implants, suggesting their effectiveness in correcting transverse maxillary defects in adults. It's crucial for treatments to improve both occlusal function and palatal morphology. Despite this, many researchers have noted that expansion treatment during mixed dentition can lead to buccal inclination in the maxillary first molar, resulting in multiple relapses. Achieving long-term stable palatal expansion without molar inclination is desirable.

The stability of palatal rugae even after orthodontic treatment has made them reliable identification markers. Various classification systems have been used to study the gross anatomy of human palatal rugae, showing good reproducibility and short-term stability. Consequently, rugae patterns are utilized in forensic medicine for identifying individuals from dental casts post-mortem.[11]

## Conclusion

- Class I malocclusion was found to have significantly larger maxillary skeletal base and intermolar widths compared to Class II and Class III malocclusions.
- Class II division 1 malocclusion showed greater palatal height and a narrower maxillary arch compared to Class II division 2. This insufficient transverse development and increased palatal height resulted in a significantly larger Korkhaus Palatal Index in Class II division 1 than in Class I malocclusion.
- Along with this, skeletal growth patterns also have an influence on palatal morphology. Where it was observed that Individuals having leptoprosopic facial form and hyperdivergent growth pattern have deeper palatal arches and constricted basal arch form whereas individuals having euryprosopic facial pattern and hypodivergent growth pattern have shallow palatal arches and wider basal arch form.
- Skeletal open bite is linked to deeper palatal arches and constricted basal arch forms, while skeletal deep bite is associated with shallow palatal arches and wider basal arch forms.
- The consistent stability of palatal rugae even after orthodontic treatment makes them reliable identification markers, which is why they are used in forensic medicine for identifying individuals from dental casts post-mortem.

Advanced imaging techniques have revolutionized the understanding of palatal morphology, enabling more accurate diagnoses and personalized treatments. Longitudinal studies on craniofacial growth and palatal morphology will enhance these insights, refine treatment strategies, and promote oral health and overall well-being.

## References

1. Khalid A, Rasheed F, Awaisi ZH. Assessment of Palatal Height Index and palatal form in different malocclusions in adult patients visiting Nishtar Institute of Dentistry, Multan. Orthod J Nepal. 2021; 11 (2): 20-4.

2. Parcha E, Bitsanis E, Halazonetis DJ. Morphometric covariation between palatal shape and skeletal pattern in children and adolescents: a cross-sectional study. Eur J Orthod. 2017;39 (4): 377-85.
3. Nanda R, Snodell SF, Bollu P. Transverse growth of maxilla and mandible. SeminOrthod. 2012; 18 (2): 100-117.
4. Kochkonyan T.Ghamdan AH, Domenyuk D, Dmitrienko S, Budaychiyeva M, Domenyuk S. Clinical types of hard palatal vault in people with various gnathic dental arches within physiologically optimal norm. Archiv Euro Medica. 2022;12 (1): 91-6.
5. Alvarez SH, Sierra A V, Sanchez G J, Botero MP. Palate shape and size and palatal rugae morphology of children with anterior open bite and normal vertical overbite. J Forensic Odontostomatol. 2018; 36 (1): 34-8.
6. Negishi S, Richards LC, Hughes T, Kondo S, Kasai K. Genetic contribution to palatal morphology variation using three-dimensional analysis in Australian twins. Arch Oral Biol. 2020;11(6):104-7.
7. Lione R, Franchi L, Ghislanzoni LTH, Primozic J, Buongiorno M, Cozza P. Palatal surface and volume in mouth breathing subjects evaluated with three dimensional analysis of digital dental casts a controlled study. Eur J Orthod. 2015; 37 (1): 101-4.
8. Alvarez SH, Sierra AV, Sanchez GJ, Botero MP. Palate shape and size and palatal rugae morphology of children with anterior open bite and normal vertical overbite. J Forensic Odontostomatol. 2018; 36 (1): 34-43.
9. Soans CR, Mohammed A, Murali PS, Mendonca M, Prajwal SV. Morphology of Palatal Rugae in Various Sagittal Skeletal Malocclusions in Kerala Population-A Retrospective Study. Indian J Forensic Med Toxicol. 2020; 4 (2): 315-7
10. Arvind TRP, Dinesh SS. Can palatal depth influence the buccolingual inclination of molars? A cone beam computed tomography based retrospective evaluation. J Orthod. 2020; 47 (4): 303-10.
11. Armstrong J, Seehra J, Andiappan M, Jones AG, Papageorgiou SN, Cobourne MT. Palatal rugae morphology is associated with variation in tooth number. Sci Rep. 2020;10 (1): 87-109.
12. Laganà G, Di Fazio V, Paoloni V, Franchi L, Cozza P, Lione R. Geometric morphometric analysis of the palatal morphology in growing subjects with skeletal open bite.Eur J Orthod. 2019; 41 (3): 258-63.
13. Huang X, Hu X, Zhao Y, Wang Y, Gu Y. Preliminary comparison of three-dimensional reconstructed palatal morphology in subjects with different sagittal and vertical patterns. BMC Oral Health. 2020; 20 (1): 55-8.
14. Buschang PH, Stroud J, Alexander RG. Differences in dental arch morphology among adult females with untreated Class I and Class II malocclusion. Eur J Orthod. 1994;16 (1): 47-52.
15. Paoloni V, Gastaldi G, Franchi L, De Razza FC, Cozza P. Evaluation of the morphometric covariation between palatal and craniofacial skeletal morphology in class III malocclusion growing subjects. BMC Oral Health. 2020; 20 (7): 1-8.

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# Prevention of Traumatic Dental Injuries; Mouthguard and Facemask

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## Abstract

Traumatic dental injuries (TDIs) represent a significant public health concern, particularly in children and adolescents, with lifelong esthetic, functional, and psychological consequences. The majority of TDIs occur in the anterior maxillary region and are often caused by falls, sports, traffic accidents, and interpersonal violence. Prevention is centered on identifying risk factors, implementing protective strategies, and raising awareness among patients, parents, educators, and healthcare professionals. Education plays a crucial role in empowering children, families, and coaches to adopt preventive behaviors and ensure proper first aid management of injuries. Protective appliances, including faceguards and mouthguards, are proven to significantly reduce the severity and incidence of dental trauma in contact sports and high-risk activities. Among these, custom made mouthguards fabricated from EVA copolymers provide superior comfort, retention, and protection, though challenges remain regarding their cost effectiveness and compliance. Despite limitations in large-scale controlled studies, evidence supports the integration of preventive orthodontics, community education, safety regulations, and the routine use of protective gear as part of a comprehensive strategy to minimize traumatic dental injuries. A systematic, multi-disciplinary approach is essential to reduce the burden of TDIs and ensure long-term oral health and quality of life.

**Keyword:** Traumatic injuries, Face mask , Mouthguard

## 1. Introduction

The word trauma is defined as an injury (wound) to living tissue caused by an extrinsic agent (Merriam Webster).[1] Dental trauma, a physical trauma affecting teeth and structures, requires immediate medical attention to prevent complications. It results in damage to various structures, necessitating a comprehensive understanding of interrelated healing patterns.[2]

Teeth can be fractured due to accidents or malicious intents, with upper jaw incisors being most susceptible. Boys may occasionally receive mouth blows during amusements, causing front tooth fractures. (Fox, 1806).[3]

Dental trauma, particularly a child's anterior tooth fracture, significantly impacts both the child and parent, especially if the injury affects permanent dentition and extensive tooth structure.[4] Clinicians must manage these traumas effectively to achieve a good, aesthetically pleasing, medium to long-term clinical outcome.

Dental trauma is common in children from an early age, as they learn to walk and explore their environment. Primary teeth traumas are mainly caused by indoor injuries like falling from baby carriages or hard objects. Frequency increases during toddlerhood due to lack of motor coordination and reflex development, which protect the face from injuries.[5] Most dental trauma occurs in the 7- to 12-year-old age group and is mainly due to falls and accidents near home or school.[2] It Occur primarily in the anterior region of the mouth, affecting the maxillary more than the mandibular jaw. Serious accidents like automobile crashes can affect any tooth and occur in all age ranges.[6]

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Minor falls, accidents, sports, or childish pranks often cause fractures and displacements in children, altering their facial appearance and potentially causing ridicule. After a traumatic dental injury, endodontic treatment is often provided for caries-free, single-rooted, young permanent teeth. However, children's tooth injuries pose unique challenges in diagnosis and treatment, with the extent of injury often inconclusive and pulpal hyperemia often unresolved by available diagnostic methods.

Preventing traumatic dental injuries is vital, especially for children and adolescents who are most vulnerable. These injuries often result from falls, sports, traffic accidents, and violence. Prevention focuses on identifying and addressing risk factors, promoting protective behaviors, raising public awareness, and minimizing exposure to situations that may cause dental trauma.

To prevent traumatic dental injuries (TDIs), use protective gear, create safer environments, and educate on injury prevention. Regular dental check-ups can identify risk factors, while community programs and school safety policies support prevention. A combined approach of education, environment, and protection is crucial for long-term oral health.

The article focuses on preventing traumatic dental injuries by identifying risk factors, promoting protective measures like mouthguards, encouraging safe environments, and emphasizing education for patients, parents, and healthcare professionals.

## 2. Prevention of Traumatic Dental Injuries

Traumatic dental and maxillofacial injuries affect 20-30% of permanent dentition globally, causing significant esthetic, functional, psychological, and economic consequences. Prevention relies on identifying risk factors and addressing risk factors.[2] Most common injuries occur in children over 7 during sports (American football, basketball, rugby, soccer, boxing, wrestling, or "stick sports".), traffic accidents, contact sports, and children's play, particularly at school.[7]

A study by Skaare and Jacobsen in Norway found that 48% of 1275 injured individuals were at school, with sports and traffic accidents being less common. Organized sports accidents represented only 8% of total injuries, similar to violence.[2] Andreasen's 2001 study found that 7% of dental trauma claims were due to organized sports in a sample of 3655, while 93% resulted from varied and unpreventable causes. Both studies concluded that preventing oral trauma is neither easy nor feasible.[8]

## 3. Education As A Preventive Strategy For Traumatic Dental Injuries

Education is crucial for preventing dental and oral injuries, targeting children, teenagers, and those nearby. Information on avoiding and managing injuries should be provided at the injury site, and dentists should discuss risk factors during routine visits. Education should be aimed at both genders, as the gap between boys and girls in sports and leisure activities is narrowing in some areas. Older data suggests boys are more prone to oral and dental injuries.

High risk individuals, including those with severe maxillary overjet, should receive special measures to reduce dental trauma risk. Preventive orthodontic treatment should be initiated before age 11, and those with a history of oral trauma are more likely to sustain new injuries. The risk of multiple injuries is 8.4 times higher when the first trauma occurs at 9 years of age. Young children should receive special attention and their activities, games, and sports involvement should be carefully assessed.

Information campaigns, including television, newspapers, brochures, and posters, can prevent traumatic dental injuries. Children should be educated on correct first aid, such as planting an avulsed tooth immediately or stoking it in milk. Posters sponsored by the International Association of Dental Traumatology reinforce this knowledge. Parents, especially during school and organized activities, should also be educated about dental trauma[8]

Table proposes a communication form based on LADT's (International Association of Dental Traumatology) guidelines, providing clear language and simple instructions on immediate dental trauma treatment. It also advises on consultation urgency for necessary dental procedures.

| Term | Type of Injury | Immediate Treatment | Dental Referral |
|---|---|---|---|
| Uncomplicated Crown Fracture | Portion of the tooth broken off. No bleeding from the fracture | None | Within 48 hours, especially if the patient has difficulty due to cold sensitivity |
| Complicated Crown Fracture | Portion of the tooth broken off and bleeding from the fracture | None; do not place any medication on the bleeding pulp. If needed have patient bite into the gauge | As soon as logistically possible; could wait until the next morning if the patient tolerates eating and drinking |
| Root Fracture | Tooth might appear in the normal position but bleeding from the gum around the tooth. The crown of the tooth might be pushed back or loose | None | As soon as possible |
| Tooth Concussion and Subluxation | Tooth still in its normal place and firm or slightly loose | None | Within 48 hours, for evaluation only |
| Luxation | Tooth very loose and/or the crown has moved from its normal position | Only move the tooth back to its normal position if it is easy to move | As soon as possible especially if it is not possible to reposition the tooth |
| Avulsion | Tooth completely out of the mouth. Replace the tooth in its hole | If not possible store the tooth in milk or the saline immediately | It is extremely important for prognosis of the tooth to be treated immediately |

## 4. Appliances To Prevent Dental Injuries

Traumatic impacts can cause tissue damage, leading to laceration, contusion, or ablation. Protective devices like mouthguards can reduce the consequences by preventing the impact from reaching the oral region or cushioning, absorbing, or distributing the force. Wearing a faceguard or mouthguard is the only way to prevent or significantly reduce the severity of dental injuries during sports and activities involving falling or hitting objects. Before the mandate for faceguards and mouthguards in high school football, facial and oral injuries constituted up to 50% of all reported football injuries.

Following a mandate, reported injuries have decreased by a few percent[8,10]. Traffic accidents are another common cause of oral injury. Many countries mandate seatbelts and helmets with chin arch for motorcycle use. Bicycling helmets provide head protection, as demonstrated in Victoria, Australia, with a 48% reduction in head injuries after a year. However, these helmets do not offer mouth or dental protection.

### 4.1 Faceguard

A faceguard is a metal or composite cage attached to a helmet or head strap, providing face and teeth protection (Fig , 1). Prefabricated or custom-made guards are available in clear polycarbonate plastic. While not applicable to all activities, mandatory helmet and facial protection has been effective in eliminating ocular, facial, and dental injuries in juvenile hockey, despite limited large-scale studies15.Danis et al.'s study found that while head injuries in youth baseball teams have decreased, catastrophic spinal injuries have increased. The study suggests that players may have a false sense of security when donning equipment, leading to excessive risks[12]. Half of the teams were provided with guard helmets, and intervention teams reported a reduction in oculofacial injuries.

A study reveals that full face shields in hockey reduce the risk of facial and dental injuries without increasing neck injuries, concussions, or other injuries, contradicting the belief that full face shields may increase neck injuries[13]. With the availability of new fiber composites, custom fabricated faceguards will become more affordable.


Fig .1: A typical cage like face mask

### 4.2 Mouthguards

Mouthguards in contact sports can reduce dental injuries by up to 90% or more[14,15]. Since the 1960s, rules regarding headgear and mouthguards in high school football have reduced facial and dental injuries by approximately 48%13. However, few studies have investigated whether athletes wearing mouthguards sustain significantly fewer dental injuries[15]. A study involving 272 rugby players found a significant difference in tooth fractures between mouthguard wearers and those without mouthguards. Studies show that mouthguards can prevent dental and orofacial injuries during sports and training. A study involving U.S. male college basketball players (ages 18–22) gathered real-time data from athletic trainers over a season, recording 70,936 athlete exposures found that wearing mouthguards led to fewer dental injuries and less dentist referrals. However, there was no significant difference in soft tissue injuries. The study also reported more oral and dental injuries than the NCAA, suggesting under reporting in official data[16].

A study at Fort Leonard Wood found that military trainees not wearing mouthguards during high risk exercises (e.g., unarmed combat and bayonet training) were twice as likely to suffer orofacial injuries compared to those who consistently wore them[9]. A cross sectional study of 321 university rugby players (555) found no significant difference in oral or dental injury rates between mouthguard users and nonusers, but its limited sample size reduces statistical power. Larger, more comprehensive studies are needed for conclusive findings[9].

### 4.2.i; Role of Mouthguards

It has been suggested that a mouthguard should protect the wearer against injuries in five different ways[18]:

- Preventing tooth injuries by absorbing and deflecting blows to the teeth
- Shielding the lips, tongue, and gingival tissues from laceration
- Preventing opposing teeth from coming into violent contact
- Providing the mandible with resilient support, which absorbs an impact that might fracture the unsupported angle or condyle of the mandible
- Preventing neck and cerebral brain injuries

Mouthguards have been tested for their protective functions using various materials and methods, but there is no ethically feasible in vivo model or large prospective cohort studies. A Japanese study found that mouthguards can protect teeth and mouth during athletic events using actual objects that could hit them[19]. The study found that transmitted forces were less when a standard single layer mouthguard was used compared to no mouthguard. The steel ball showed the highest absorption ability (62.1%), followed by the wooden bat (38.3%). The study suggests testing mouthguard effectiveness on specific types of sports equipment instead of standard experimental equipment.

Materials' physical and mechanical properties vary based on chemical composition and brand. PVAc-PE materials' resilience inversely correlates with impact energy magnitude, possibly due to cross linking, plasticizer proportion, and filler particle volume. Laminated thermoplastic mouthguards offer stability but not maximum protection[20].

The fifth suggested protective role of mouthguards is to prevent neck or cerebral brain injuries. However, most articles are case reports or opinions, not based on controlled scientific studies. The two articles cited as a foundation of this presumed preventive effect were written by Stenger and colleagues[21] in 1964 and Hickey and colleagues[22] in 1967, the claim of mouthguards' protectiveness on cerebral injuries has been called into serious question. Two large studies using an interactive website to collect weekly information on the incidence of cerebral brain concussion in athletes have failed to show any benefits. The first study compared mouthguards with no mouthguards in US College men's basketball (71,000 athletic exposures were reported) and boil-and-bite versus custom-made mouthguards in American college football (500,000 athletic exposures were recorded), but found no significant difference in the rate of brain concussion between the groups[9]. A study comparing the Wipss Brain Pad padded dual jaw mouthguard to other mouthguards found no significant difference in concussion rates between players wearing the Wipss Brain Pad mouthguard and those using other types. Manufacturers of stock mouthguards have made unsubstantiated claims about their products, marketing them under brand names like "Brain Pad" and "Brain Pad plus."[23]

**4.2.ii; Types of Mouthguards**[236]

Mouthguards can be divided into 3 basic types based on how they are manufactured and used:

- Stock prefabricated
- Mouth formed
- Custom made

Some of these basic types now have several subgroups, especially the custom made ones. Stock mouthguards, made from rubber or plastic, come in 2 or 3 sizes and have a universal fit. They often have flanges in the molar area, but their loose fit can obstruct speech and breathing. They're inexpensive and easily available in sports shops[24,25].

Mouthguards can be uncomfortable and ineffective due to poor fit, obstructing speech and breathing. Two types of mouth formed mouthguards are available: rigid with a rigid outer shell and soft with a resilient lining. The outer shell may be lined with self curing rubber, and the shell is fitted around sulci and frenal attachments. The mouthguard should be placed centrally, polymerized for 3 to 5 minutes, and trimmed with a sharp knife, but may be bulky and sharp if the lining material is inadequate (Fig 2).

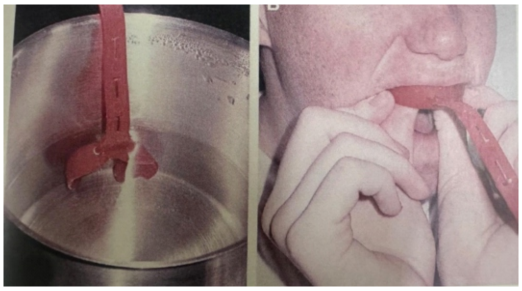

**Fig 2 : Boil bite is being formed in the mouth**

Mouth formed protectors are mouthguards made from a preformed thermoplastic shell, like PVAc-PE copolymer or PVC8, that are softened and molded in the mouth by the user. They offer advantages over stock mouthguards, such as a closer fit and easier retention, but require careful molding to avoid gingiva burning. Custom mouthguards, made from plaster of Paris models, are more comfortable but have no evidence of effectiveness in preventing injuries[26,27].

Historically, three materials were used: molded vulcan rubber, latex rubber, and resilient acrylic resins. EVA copolymers are the most common due to their elastomeric softness, flexibility, ease of processing, clarity, gloss, barrier properties, low temperature toughness, stress crack resistance, and minimal odor.

EVA plates, with varying percentages of vinyl acetate, are more flexible, stretchable, softer, and tougher due to lower softening temperatures (Fig 3). Common EVA copolymers for mouthguards contain 28% vinyl acetate. Performance depends on material properties, design, thickness, and traumatic impact. EVA mouthguards come in varying colors, thickness, and hardness, with debates about recommended stiffness or hardness for different sports. Clinical studies are lacking..

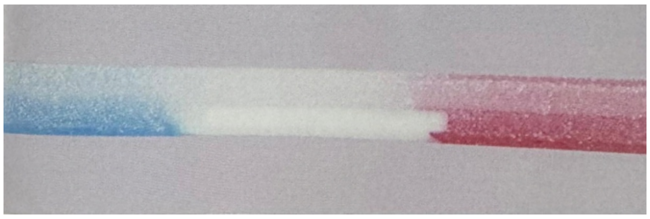

**Fig 3: Prefabricated double layered mouthguard stock plate .Both layers contains the same percentage of vnyl acetate, but the top layer is clear and the bottom layer is composed of three different colours, all fused into one mass, for esthetic reasons**.

In 1985, Chaconas et al. introduced a laminated thermoplastic mouthguard that showed less dimensional change than other materials tested. This led to the introduction of layered EVA stock plates to strengthen the mouthguard without reducing its protective capacity. However, this stretching can affect the plate's properties depending on whether the grains are running lingually or mesiodistally on the tooth. Manufacturers now sell two or three layered stock EVA, with layers added perpendicular to each other. However, there is little scientific proof that this increases the mouthguard's protectiveness, and concerns have been raised about potential tooth or alveolar damage[28].

A study found that a hard insert in mouthguards reduced energy absorption, while EVA mouthguard material with regulated air inclusion improved impact characteristics. However, no clinical data supports this. Another layered concept improved when softer material was next to teeth. A study by Kim and Mathies[9] showed that a soft outer layer did not significantly change stress distribution and impact force.

A study on 96 professional rugby players found custom-made mouthguards significantly reduced dental injuries compared to stock and mouth-formed mouthguards[29]. However, no teeth were damaged during follow-up clinical examinations. Users preferred laboratory formed mouthguards for comfort.

A study on college football players found no difference between boil and bite and custom made mouthguards, highlighting the need for larger sample sizes in future research.

A study involving 87 Division I teams (506,297 athletic exposures) found that most used a mixture of custom and boil and bite mouthguards. A sub-selection of 14 teams found no significant benefit of one type over the other. A recent study found a significant protective effect of custom-made mouthguards compared to stock mouthguards, but reported head and oral injuries combined. The study also lacked a control group for wear and tear, suggesting regular replacement due to lack of fit and reduced protective properties. A simulated aging study showed dimensional changes induced by aging, with pressure laminated mouthguard specimens showing the lowest range of changes, suggesting improved fit, comfort, and protection.

**4.2.iii; Fabrication of Mouthguards**

The Federation Denture International (FDI) has published recommended criteria for creating an effective mouthguard, with most of these guidelines stating the same things.

1. The mouthguard should be made of a durable material that can be easily washed, cleaned, and disinfected.
2. The device should provide sufficient retention for optimal positioning during sports and maintain a normal occlusal relationship for optimal protection.
3. It should absorb and disperse the energy of a shock by:

- Covering the maxillary dental arch
- Excluding interference
- Reproducing the occlusal relationship
- Allowing mouth breathing
- Protecting the soft tissues

The FDI recommends dentists create mouthguards using an athlete's teeth impression.

### Fabrication of a Mouth formed Mouthguard

The key to a mouth formed mouthguard's functionality is selecting a stock that fits the arch, as too small may not cover molars properly, reducing retention and fit. After finding the correct size, the mouthguard should be made following manufacturer's guidelines or recommendations( Fig 4).

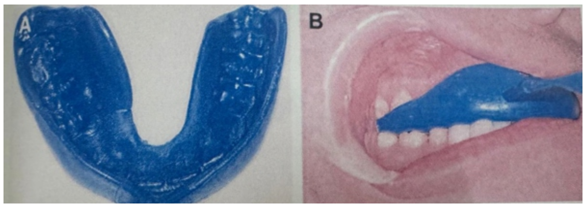


Fig 4: Selection of a stock mouthguard that fit the arch is important when making a boil and bite mouthguard

### Fabrication of a Custom made Mouthguard

Custom mouthguards require a stock that fits the arch, as too small can reduce retention and fit. Following manufacturer's guidelines is crucial for fabrication. To construct a mouthguard, take alginate impressions of both arches and a wax bite with the patient's mandible in a physiologic rest position. A good impression of the alveolus over all teeth is essential for good adaptation of the mouthguard material to soft tissue area, ensuring better retention and comfort and the vestibule is overextended (Fig 5).

Fig 5: The impression should include not only teeth but also the alveolar tissue up to the vestibule

A study found that increasing the labial extension 2mm of the mouthguard, adjusting it for even occlusal contact, rounding at the buccal peripheries, and tapering at the palatal edges can increase comfort of wear. To ensure good adaptation, the cast should be carefully trimmed, allowing the vestibule to be almost removed (Fig 6).Vacuum-forming machines determine the fit of mouthguards by residual moisture in the working cast, which is best achieved when dried and surface temperature is elevated[29].

Fig 6: The cast should be trimmed so that the vestibule is almost removed ensuring a good adaptation

There are two basic methods of fabricating a custom made mouthguards.

Custom mouthguards can be fabricated using traditional vacuum suction machines (Fig 7) or prefabricated multilayered EVA. However, creating multilaminated mouthguards from separate plates is challenging due to poor adaptation and high failure risk.

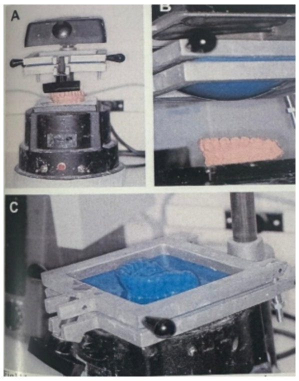


**Fig 7: (A) A traditional vacuum suction machine used to make custom-made mouthguards. At the top is the heating element. The stock plate is sandwiched into a metallic device underneath the heating element. The cast is placed and centered on a perforated plate. (B) When the stock plate heats up, it will start to droop downward (in what has been called a "wine gum" stage) until it has dropped about 2.0 to 2.5 cm (0.75 to 1 inch). (C) Before it is removed from the cast, the plate needs to cool down completely.**

To create a mouthguard, follow these three steps:

1. Drill a hole in the palatal area of the cast to improve suction and adaptation (Fig 8 )
2. Allow the heated EVA plate to adapt well to the cast and cool in place;
3. Properly trim the mouthguard after it has cooled completely
4. Extend the mouthguard as far into the vestibule as tolerated by the patient, with appropriate clearance of the buccal and labial frenula (Fig 9)
5. Cover at least up to the second molar distally. (Fig 10)

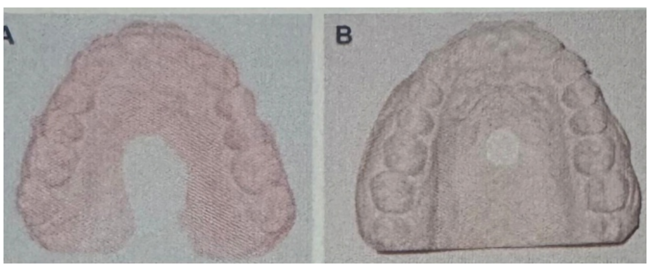


**Fig 8: Drill a hole in the palatal area of the cast to improve suction and adaptation**

**Fig 9: Extend the mouthguard as far into the vestibule as tolerated by the patient**


**Fig 10 : Cover at least up to the second molar distally**

Trim the mouthguard with a heated knife or scissors, replace it, flame the edges with a torch, or smooth them with a hand trimmer. To improve comfort, gently heat the occlusal surface and have the athlete bite together with the guard in place.

II. Positive pressure machines like Drufomat, Erkopress-2004, or Biostar can create custom mouthguards by pressing the stock plate onto the cast, ensuring close adaptation. This method allows for multiple layers of stiffness without losing tooth adaptation, but requires resilience. It also allows sandwiching of names, numbers, or logos between layers. Mouthguards should be inspected for quality and thickness, with thicker ones providing more protection. However, thickness exceeding 4 mm can marginally improve performance and make the mouthguard less comfortable. Overall, this method offers a flexible and cost effective solution for custom mouthguards[29].

Common pitfalls in creating custom made mouthguards include:

1. Extension above the teeth: The more the gums are covered above the teeth, the greater the retention. Mouthguard's strength increases as well. Over extension is uncomfortable and could lead to injury in the vestibule. The mouthguard should be trimmed so that the frenulum is free.
2. Extension over the molar area: The mouthguard should cover at least one molar tooth on each side. Some extension over the gums in the molar region is recommended for retention.
3. Extension in the palatal area: The mouthguard needs to cover some of the tissue above and behind the anterior teeth. This fit will increase retention and strength of the mouthguard.
4. Rough edges: Rough edges are uncomfortable and cause additional injuries. They should be smoothed with a flame, sandpaper, or rag-wheel.
5. Too thin or too thick: mouthguard that is too thin will not be strong enough to provide protection. mouthguard that is too thick will be uncomfortable to wear.

**Use of Mouthguards**

Mouthguards are used as preventive devices for traumatic dental injuries during sports activities like football, baseball, basketball, boxing, field and ice hockey, and rugby. However, their protective role remains questionable. Mouthguards should be connected to a facemask or helmet. (Fig 11) They also offer protection for dental tissues during general anesth-esia, as tooth fractures or displacement can occur.

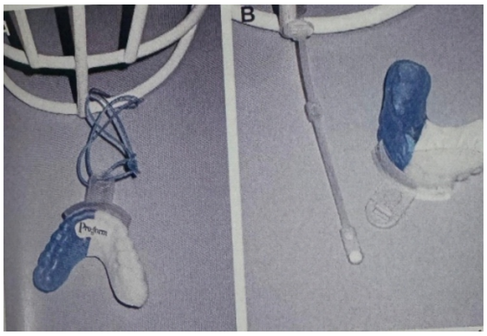

Fig 11: Mouthguards should be connected to a facemask or helmet

Teeth injuries during general anesthesia delivery can be caused by using the incisal edges of anterior teeth as a fulcrum. Custom-made mouthguards are not cost effective due to concerns about intubation. However, a recent study showed an average 7-second difference in intubation time between patients with and without mouthguards. The cost of legal action due to dental trauma makes the case for dental protection during intubation stronger. Protective dental appliances are recommended for situations with high risk of complications[30].

## Conclusion

Permanent teeth injuries are crucial for their vitality and speech function. Common injuries include falls and sports activities, leading to orofacial injuries. Fractures can cause pulp complications, vestibular sinus tract appearance, or crown color changes. Treatment strategies are based on pulp and periodontal ligament vitality. A systematic approach is essential for traumatized children, with periodic monitoring for successful intervention. Endodontic treatment is recommended for cases of spontaneous pain, abnormal response to pulp tests, lack of root formation, or apexogenesis. A splint may be necessary to stabilize a tooth following traumatic injury. Traumatized primary teeth can lead to difficulties in the permanent tooth, such as enamel hypoplasia, hypocalcifi-cation, crown/root dilaceration, or eruption abnormalities. Informing patients about potential consequences is essential for prompt action and reducing complications. Successful therapy depends on the child's age, trauma type, severity, and time between dental trauma and care.

## Reference


1. The Meriam-Webster's collegiate dictionary. Tenth Edition( 1999)
2. Skaare AB, Jacobsen I. Dental injuries in Norwegians aged 7-18 yearS. DetaTraumatology. 2003 Apr;19 (2); 67-71.
3. FoxJ. The history and treatment of the diseases of the teeth. the gums, and the alveolar processes, with the operations which they respectively reque
4. Observations on other diseases of the mouth. Artificial teeth. James Swa,1806.
5. Ripa LW, Finn SB. The care of iniuries to the anterior teeth of children, Clinical Pedodontics, 4th Edition 1995. W.B Saunders Company.
6. Kalwitzki M, Weiger R. An intrusion injury as an example of interdisciplinary aspects in dental traumatology: A case report. Ouintessence international.2005 Mar 1:36 (3).
7. Hargreaves KM, Berman LH. Cohen's pathways of the pulp expert consult. Elsevier Health Sciences; 2015 Oct 2.
8. Bassat YB, Brin I, uks A, Zilberman Y. Elfect of trauma to the priTaryincisors on permanent successors in different deve-lopmental stages. PedialrDent. 1985 Mar; 7: 37-40.
9. Andrcasen JO, Andreasen FM, Andreasen L. Text book and color atlas of traumaticinjuries to the teeth :4" Ed: Copen-hagen Musksgaard, 2007
10. Bourguignon C, Sigurdsson A. Preventive strategies for traumatic dontatiniuries. Dental Clhnics. 2o09 Oct ; 53 (4): 729.49.
11. Crescini A, Doldo T. Dilaceration and angulation in upper incisors conscquentto dental injuries in the primary denti-tion: orthodontic management. Progressin Orthodontics. 2002 Jan; 3 (1 ): 29-41.
12. Frederico Cunha R, CarvalhoPugliesi DM, Guimaraes Correa M, MarcosAssuiti D. Early treatment of an intruded primary tooth: a case report. Journalof Clinical Pediatric Dentistry. 2001 Apr 1: 25 (3): 199-202.
13. Danis RP, Hu K, Bell M. Acceptability of bascball face guards and reduciionof oculofacial injury in receptive youth league players. InjPrev 2000; 6: 232-4.17
14. Benson BW, Mohtadi NG, Rose MS, et al. Head and neck injuries among 1ee hockey players wearing full face shields vs half face shields. J Am MedAssoc 1999; 282: 2328-32.
15. Da Silva AC, De Moraes M. Bastos EG, Moreira RW, Passeri LA. Toothlragment embedded in the lower lip after dental trauma. Dental Traumatology. 2005 Apr; 2 1 (2): 115-20
16. Demarco FF, Fay RM, Pinzon LM, Powers JM. Fracture resistance of re-attached coronal fragments influence of different adhesive materials andbevel preparation. Dental Traumatology. 2004 Jun:; 20 (3): 157-63
17. Barbic D, Pater J, Brison RJ. Comparison of mouth guard designs andconcusSlon prevention in contact sports: a multi-center randomized controlledtrial. Clin J Sport Med 2005; 1 5 (5): 294-8
18. Finch C. Braham R, McIntosh A, et al. Should football players wear custom fitted mouthguards? Results from a group randomiscd controlled trial. InjPrev 2005; 11 (4): 242-6
19. Nicholas NK. Mouth protection in contact sports. NZ Dernt J 1969; 65:14-24,
20. Wetzel RC. Defective dentition following mechanical ventilation. The Journalof pediatrics. 1980 Aug 1; 97 (2): 334.
21. Hedegard B. A study of traumatized permanent teeth in children aged 7-15years. Part I. Swed. Dent.J.. 1973: 66: 43 1-50

22. Hargreaves JA, Matejka JM, Cleaton-Jones PE, WilliamsS. Anterior toothtrauma in eleven-year-old South African children. ASDC journal of dentistry for children. 1995; 62 (5): 353-5
23. Peterson EE. Andersson L, So' rensen S. Traumatic oral vs non-oral iniuries An epidemilogical study during one year in a Swedish county. Swed Dent I1997; 21:55-68.
24. Pattussi MP, Hardy R, Sheihan A. Neighborhood social capital nd dental injuries in Ryviian adolescents, American Journal of Public Health, 2006 Aug: 96 (8): 1462-8
25. Soriano EP, Caldas Jr AD, Carvalho MV, AmorimFilho HD, Prevalence and risk factors relatcd to raumatie dental injuries in Brazilian Nchoolchildren, Dental traumatology. 2007 Aug: 23 (4): 232-40.
26. Bendo CB, Paiva SM, Oliveira AC, Goursand D, Torres CS, Pordeus IA, Vale MP. Prevalence and associated factors of traumatic dental injuries in Brazilian schoolchildren. Journal of public health dentistry. 2010 Sep, 70 (4): 3 13-8
27. Harding AM. , Camp JH. Traumatic injuries in the pre-school child. Dent. Clin. North Am. 1995; 39: 817-835
28. Park JB. Shaull KL, Overton B, et al. Improving mouth guards. J Prosthet Dent 1994: 72: 373-80.
29. Gutmann JK, Gutmann MS. Cause., incidence, and prevention of trauma to teeth. Dent Clin North Am 1995; 39: 1-13.
30. Skeie A, Schwartz O. Traumatic injuries of the teeth in connection with general anaesthesia and the effect of use of mouthguards. Endod DentTraumatol 1999:15:33--6.

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# Labial Frenum and Its Role In Midline Diastema A Narrative Review

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## Abstract

**Introduction:** The intricate interplay between oral anatomy and dental anomalies continues to fascinate researchers. Among these, association between the labial frenum and the maxillary midline diastema stands as a compelling subject of investigation.
**Aim :** This narrative review aims to analyse the association between the labial frenum and midline diastema. This review explores the epidemiological, anatomical, etiological, and clinical treatment aspects of this association.
**Methods:** Research publications were searched for 4 months on PubMed, Web of Science, Scopus, and Google Scholar and the articles with the terms labial frenum, midline diastema, treatment timing were collected.
**Results:** A total of 40 articles were collected and they were further used to formulate this review.
**Discussion:** An abnormally large labial frenum is positively associated with a maxillary midline diastema. Epidemiological studies reveal varying prevalence rates of midline diastema across different populations and age groups. Treatment modalities include surgical techniques, electrocautery, and lasers, each with its advantages and considerations. Frenectomy is mostly recommended after the eruption of permanent canines and maybe done priorly or following orthodontic therapy depending on the diastema severity.
**Conclusion:** At present, there are no standardized national or international protocols for diagnosing and managing an abnormal frenum.
**Keywords :** Labial Frenum, Maxillary Midline Diastema ,Frenectomy

## Introduction

The intricate interplay between oral anatomy and dental anomalies continues to fascinate researchers and practitioners alike, as they strive to unravel the mysteries surrounding the etiology and management of various oral conditions. Among these, association between the labial frenum and the maxillary midline diastema stands as a compelling subject of investigation.

Diastema, a word derived from the Greek language, means the presence of a space between two adjacent teeth. While, historically considered primarily an aesthetic concern, recent studies have shed light on its potential functional and developmental implications. The diastema maybe observed in children as a physiological process in the mixed dentition, which gradually disappears with the eruption of the permanent dentition.[1,2] Moreover, as a child undergoes craniocaudal growth, a thicker frenum tends to transition into a simpler one, consequently resulting in the closure of the diastema.[3]

In 1907, Angle defined the midline diastema as a prevalent type of incomplete occlusion marked by a space between the maxillary central incisors.[4] Similarly, Andrews in 1972, gave "The six keys to normal occlusion" where the fifth principle states that interdental diastemas should not exist and that all contact areas should be tight, so that the patient has "straight and attractive teeth, as well as a correct overall dental occlusion".[4]

Potential causes of a midline diastema include genetic factors, missing or supernumerary teeth, odontomas, cysts, discrepa-

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ncies between tooth and jaw size, anomalous positions of teeth, digit sucking habits, impe-rfect fusion at premaxillary midline, and abnormal frenum attachment.[2,5]

A frenum is a fibrous tissue band that connects to the maxillary bone, which is com-monly superficial to the muscle attachments. An abnormal frenum maybe thick or hyper-trophic and has been associated with issues such as papillary loss, recession of gingiva and gingival sulcus distension. This may further promote accumulation of plaque and worsen periodontal pockets. Additionally, it may be responsible for midline diastema, and pose difficulty in oral hygiene mainte-nance.[2]

Abnormal frenal attachments can be visually detected by the blanching test, where tension is applied over it to detect the movement of the papillary tip or blanching due to ischemia. A frenum can present a significant issue when the movement of the lips causes tension, which pulls the gingival margin from the tooth or when it obstructs the closure of a diastema during orthodontic treatment.[3] In 1939, Hirschfield advocated frenectomy as a mucogingival procedure to resolve the afore-mentioned pathologic conditions.[6] Frenectomy can be per-formed using various techniques which can be divided under surgical, electrocautery and lasers.

However, a difference in opinion amongst clinicians exists with respect to need and timing for intervention. The question persists as to whether the frenectomy should be conducted prior to or following the eruption of the permanent maxillary canine, and how this timing correlates with orthodontic intervention. In this exploration, we delve into the role of the labial frenum in midline diastema formation, examining the anatomical forms, developmental considerations, and clinical implications.

## Method

Research publications were searched for 4 months on PubMed, Web of Science, Scopus, and Google Scholar and the articles with the terms labial frenum, midline diastema, treatment timing, and orthodontics were collected. Further, all those articles were analyzed to determine the role of labial frenum in maxillary midline diastema.

## Results

Finally, 40 articles were collected and they were used to formulate this review.

## Discussion

From an anatomical perspective, the labial frenum originates from the inner surface of the upper lip. Typically, it originates with a wise base, characterized by a smooth septum that tapers gradually as it traverses backward to connect at the midpoint between the outer layer of the periosteum and the connective tissue of the intermaxillary suture and the alveolar process. The labial frenum displays diversity within normal parameters and may range from a bulky mass to a thin tissue fold, and in its attachment height from close to the alveolar crest to significantly above it.[6]

Clinicians must first accurately diagnose an abnormal labial frenum in patients presenting with maxillary midline diastema and eliminate other potential causes. This requires a comprehensive understanding of the several types of labial frenum, both normal and abnormal, their prevalence, and other contributing factors. Once the abnormal labial frenum is identified as the causative factor for the diastema, decisions must be made regarding when and how to proceed with frenectomy, while considering its impact on orthodontic space closure.

As we delve into the epidemiology section, understanding the prevalence and patterns of abnormal labial frenum in the context of maxillary midline diastema becomes paramount.

## Epidemiology

According to epidemiological investigations, the prevalence of median diastema is higher in children, and it decreases dramatically between 9 to 11 years of age, and continues to gradually decrease up to 15 years.[4]

Taylor found that among Californian children aged 12-18 years, the prevalence of midline diastema was 7%. Similarly, studies conducted on Caucasian children in the United Kingdom by Weyman and Gardiner reported prevalence rates of 4-6.8%. Horowitz documented a prevalence of 8% for Caucasians and 19% for individuals of African descent. Lavelle reported varying prevalence rates of 3.5%, 3.4%, and 5.2% for Caucasians, Mongoloids, and individuals of African descent, respectively. McVay and Latta observed prevalence rates of 9.6%, 12.5%, and 16.3% for midline diastema ranging from 0.5 to 1.49 mm among Caucasians, Mongoloids, and individuals of African descent, respectively. Additionally, in the same study, prevalence rates of 10.4%, 7.6%, and 12.9% were noted for midline diastema exceeding 1.5 mm among Caucasians, Mongoloids, and individuals of African descent, respectively. The prevalence of midline diastema varied across different populations, with rates reported as 12.59% in Pakistan, 3.4% in the United Kingdom, and 1.6% in South Indians, according to multiple studies.[4]

Boutsi and Tatkis checked the prevalence of various frenal morphologies in children of majorly of Greek population and reported that gingival frenal attachment was present in 41.6%, followed by papillary penetrating in 26.1%, papillary in 22.1%, and mucosal in only 10.2%. Children with mucosal or gingival type of frenal attachment were significantly greater in age than those with papillary penetrating type frenum.[7] These results were consistent with those of Zakirulla et al who evaluated frenal attachments in Saudi patients and identified the gingival frenum as the most common, seen in 63% and mucosal frenum being the least common, seen in 9%.[3]

Christabel also found the gingival type of frenal attachment in 49.5% of the children in Chennai followed by mucosal type of attachment in 38.8%, 9.8% were papillary type and 1.9% were papillary penetrating type. A significant association with age was seen with the occurrence of papillary penetrating type decreasing with age.[8]

Jonathan PT and Pizán discovered that the predominant morphological form of the maxillary labial frenum was the simple type, and this occurrence notably increased with age.[9,10]

Omotoso and Kadir found that females had a predilection for maxillary midline diastema.[4] Nainar, Gnanasundaram and Al-Huwaizi demonstatred a higher prevalence of midline diastema in males than females. [4,16] Genetic factors are mostly responsible for the male-female differences. Elizabeth, Christabel, Dasgupta and Rajani agreed that no gender wise difference was seen. [7,8,11,12] After understanding the prevalence of abnormal frenal attatchments, it is important for the clinician to be able to diagnose the frenum according to various morphotypes, level of attactchment and functionality.

## Classification

Sewerin's [13] (1971) classification based on morphotypes:

1. Frenulum normale, (60.2 %)
2. Appendix frenuli (19.9 %)
3. Nodulus frenuli (9.1 %)
4. Frenulum bifidum (3 %),
5. Recessus frenuli (2.8 %),
6. Frenulum tectolabiale persistens (2.6 %) and
7. Duplicatio frenuli (0.4 %)
8. Frenum with 2 or more variations presenting at the same time (2.1 %)

Mirko[14](1974) morphological-functional classification according to the site of the attachment

1. Mucosal Attachment
2. Gingival Attachment
3. Papillary Attatchemnt
4. Papilla Penetrating Attatchment

Kotlow[15] (2004) classified based on functional evaluation of the frenum as it interferes with breast feeding.

1. **Grade 1 :** minimal alveolar mucosa and minimal attachment;
2. **Grade 2 :** frenum attaches primarily into gingival tissue at the junction point of the free and attached gingival margins;
3. **Grade 3 :** frenum inserting just in front of the anterior papilla;
4. **Grade 4 :** frenum attaching just into the anterior papilla and extending into the hard palate.

The labial frenum displays diverse configurations, and maybe responsible for a maxillary midline diastema. However, there are other contributary factors in the development of MMD, which the clinician must be able to identify and rule out before undergoing the procedure of frenectomy.

## Etiology

It is crucial to differentiate between physiological and pathological diastemas along with other contributary elements such as genetic, environmental, and behavioral influences.

Physiological diastemas are viewed as part of the natural process during the mixed dentition phase, maxillary midline diastema may emerge due to the expansion of the jaw width in anticipation of the permanent teeth which are larger in size. The unerupted permanent canines in the maxilla are positioned superiorly and distally to root apices of the lateral incisors. They exert a medially directed pressure on the roots of the lateral and central incisors resulting in a fan shaped spacing between the crowns. This was described by Broadbent as the ugly duckling stage and it resolves soon after the eruption of permanent canines.[4]

Moyers in 1988 stated the following contributary factors-

- Imperfect fusion of premaxilla at midline in 32.9%,
- Enlarged upper labial frenum in 24.4%,
- Due to normal growth in 23.2%,
- Congenitally absent lateral incisors in 11%,
- Supernumerary teeth near the midline in 3.7%,
- Unusually small teeth,
- Combination of imperfect fusion and congenitally absent lateral incisors.

Additional factors contributing to the occurrence of a maxillary midline diastema, as mentioned in literature, include rotated teeth, oral habits like thumb or digit sucking, or improper tongue positioning. Orthodontic treatment with rapid palatal expansion, distally or labially inclined maxillary central incisors, generalized spacing and pathologic teeth migration due to periodontal disease are cited as other potential causes.[4]

An abnormal frenum might exhibit increased thickness and have alveolar attachment between the maxillary central incisors and detectable continuity with the incisive papilla. Primarily, there are two mechanisms through which an abnormal frenum can contribute to a midline diastema. In the first scenario, the majority of frenum fibers maintain their embryological connection with the incisive papilla, thus obstructing approximation of the central incisors. Alternatively, these fibers may disrupt fibers of the periodontal ligament between the central incisors, creating a weak point in the continuous chain of fibers that links the teeth across the dental arch. [16]

Edwards discovered a strong association between an aberrant frenum, combined with vertical osseous cleft detectable on x-ray and the presence of a midline diastema. [17] According to Elfadel and Abuaffan, a high labial frenum attachment was the most common cause of midline diastema and was found in 51.9% of the cases. [18] Additionally, Shashua and Artun also demonstated a correlation between the width of the diastema and the presence of an abnormal frenum. [19] Moyers, Nuvvula, Harikrishnan, and Hasan concurred that a prominent labial frenum was a significant contributing factor, accounting for 24% to 39.83% in the development of a MMD.[4,6,20,21]

Gass showed heritability in the white sample to be $0.32 \pm 0.14$ and $0.04 \pm 0.16$ in the black sample. A potential genetic underpinning was proposed for MMD, with a higher impact of environmental influences observed in the black study group compared to the white study group. Nainar and Gnanasundaram, Shashua and Artun, and Gardiner and Schmitt have all suggested the involvement of a genetic component in the expression of MMD.[3] Mumtaz and colleagues discuss an autosomal dominant mutation in EDAR, which can result in dental agenesis, potentially contributing to a maxillary midline diastema and prominent frenum.[22]

Once the abnormal frenum has been established as the definite cause for the MMD, the clinician must now decide when to conduct the frenectomy procedure.

### Treatment Timing

The optimal timing for performing a maxillary labial frenectomy to address a midline diastema is a subject of debate. A common approach is to consider whether the permanent maxillary canines have erupted, after which the diastema often resolves. Hence, frenectomy is often recommended after the permanent canines have erupted. Certain cases with a large diastema may require frenectomy to be performed before canine eruption where spontaneous closure is questionable. Usually with a diastema wider than 3 mm, treatment should be initiated before permanent canine eruption.[2]

Shah and colleagues recommended certain criteria as the optimal standard: all six permanent upper front teeth should have erupted fully, closure of the diastema should be achieved using orthodontic fixed appliances, a hypertrophic frenum should show a positive response to the 'blanche test' and a large midline maxillary suture should be evident, with indications of clefting on radiographic examination. Additionally, they suggested that patients under the age of 10 or 11, without erupted canines, should not undergo an upper labial frenectomy.[23]

The American Academy of Pediatric Dentistry also states that frenectomy should be performed when the MMD >2 mm with a positive blanch test and after the permanent dentition has erupted.[3]

However, on the contrary according to Kotlow, the most favorable timing for revising the frenum, if not addressed during the early stages of primary dentition, is when the two central incisors have erupted by approximately 2-3 mm. During this phase, the emergence of the lateral incisors assists in naturally closing the diastema once the frenum tissue is excised. There were no reported instances of adverse scarring, and it was advised to conduct the frenectomy prior to commencing orthodontic procedures.[15]

According to Sanin's findings: a 1 mm gap in the early mixed dentition has a 99% chance of closing on its own, while a 1.5 mm gap has an 85% likelihood. However, for a 1.85 mm diastema, the chance drops to 50%, and for a 2.7 mm space, it dwindles to just 1% without intervention.[4]

A literature review indicates that orthodontists often recommend frenectomy after completing orthodontic treatment. This stems from the belief that granulation and scar tissue resulting from frenectomy might disrupt orthodontic procedures, possibly compromising the final results.[2] Advocates of this approach also propose that orthodontic forces could induce remodeling of the frenum. This remodeling is theorized to stimulate turnover of the trans-septal periodontal ligament fibers, potentially enhancing stability of the incisors.[24]

Frenectomy prior to orthodontic treatment is advised when the frenum is excessively large and could impede orthodontic space closure. Conducting the procedure early offers the benefit of easier surgical access, which might become restricted after orthodontic closure, potentially complicating the complete removal of all residual fibrous tissue from the interdental suture area Moreover, performing the frenectomy beforehand may promote faster approximation of the incisors.[24]

The prevailing belief that advises against treating an abnormal frenum due to concerns about potential scar tissue lacks substantiation in evidence based literature. Baxter and colleagues demonstrated the feasibility and predictability of significantly reducing the size and impact of a diastema in both primary and permanent dentition in numerous instances. The utilization of modern tools and techniques demonstrated a lack of damaging scar tissue. Maxillary labial frenectomy followed by proper postoperative care can offer advantages without posing significant risks of harm or impeding future orthodontic closure.[25]

Despite the current research on frenectomy and maxillary midline diastema, there exists a lack of consensus among dental surgeons, and this divergence of opinions is reflected in scientific literature. Finally, the timing of frenectomy in the management of midline diastema should be based on a comprehensive evaluation of dental development, severity of diastema, the morphology of the frenum and its impact on oral function and aesthetics. Early intervention may be warranted in cases of significant diastema in children to prevent further progression and address functional concerns, but individualized assessment is essential to determine the most appropriate timing for intervention.

### Treatment Modalities

Frenectomy can be performed using various techniques which can be divided under surgical, electrocautery and lasers.

In 1961, Archer and Kruger introduced the classical technique of frenectomy where healing takes place by primary intention. There is initial hemorrhage followed by approximation of cut wound ends due to epithelial cell migration and proliferation. It is easy to perform but the longitudinal surgical incisions and resultant scarring may contribute to periodontal issues and an aesthetically displeasing appearance, prompting the need for additional modifications. Hence, the scar tissue formation contraindicates the conventional frenectomy procedure prior to orthodontic treatment, as it prevents closure of midline diastema. Another disadvantage of the surgical technique is the need for sutures which may interfere with functions such as speech and food intake, and cause discomfort. Since the traditional procedure of frenectomy was introduced, several modifications like the Miller's technique, V-Y plasty and Z-plasty have also been developed.[26,27]

The electrocautery procedure provides the benefit of quick execution and a bloodless field, without the need for sutures. David and colleagues studied mucosal incisions made by scalpel, CO2 Laser and electrocautery, where electrosurgery scored highest, followed by the CO2 laser in terms of ease of use. Electrosurgery unit was also faster when the speed of incisions and excisions was compared to the CO2 laser. In comparison to the laser group, the electrocautery group experienced lesser collateral tissue damage.[28] However, electrocautery is linked with specific risks, which encompass burns, the potential for explosion with combustible gases, disruption of pacemakers, and the generation of surgical smoke.[26]

Lasers like the Diode, CO2, Nd:YAG, and Er:YAG are swiftly replacing the traditional treatment modalities. Diode lasers offer numerous advantages over traditional scalpel surgeries, they create a relatively bloodless surgical field, promote wound sterilization, require minimal suturing, and reduce surgical time. A key advantage of utilizing dental lasers lies in their capacity to interact selectively and precisely with diseased tissues which leads to limited scarring and contraction.[27]

Studies have shown that patients who underwent laser treatment had reduced pain and discomfort levels than patients treated with scalpel surgery. This may be attributed to a protein coagulum which forms over the wound and acts as a biological dressing, sealing the sensory nerve endings. Additionally, photobiomodulation properties of lasers may also act as an advantage. Histologically, laser wounds exhibit a notably reduced presence of myofibroblasts, leading to diminished wound contraction and scarring, ultimately resulting in enhanced healing. Hence, the laser technique offers superior healing outcomes when compared to surgical techniques.[29]

However, on the contrary a study by Patel RM states better wound healing was seen in the conventional scalpel technique. This maybe due to the primary closure achieved in scalpel surgery. Delayed healing was noted in laser surgery due to the charring and carbonization induced by laser radiation. Other complications include photo acoustic injuries and inadvertent laser-induced thermal necrosis. [29] While non-traditional approaches like electro surgery and lasers offer their own advantages over the conventional scalpel, there remains potential for further refinements in addressing this issue.

At present, there are no standardized national or international protocols for diagnosing and managing an abnormal frenum. Conducting further longitudinal studies could yield substantial evidence.

## Conclusion

The intricate relationship between the labial frenum and midline diastema emphasizes the complex dynamics of oral anatomy and its implications for dental health. Throughout our exploration, we uncover multiple pivotal insights:

Firstly, epidemiological data shows the varying range of prevalence of midline diastema across different age groups and ethnicities. The prevalence of median diastema is higher in children, and it decreases dramatically between 9 to 11 years of age as the permanent dentition erupts. This knowledge helps in informed clinical decision making.

Secondly, the labial frenum has diverse morphotypes and attachment levels. Understanding these variations is essential for accurate diagnosis and treatment planning. Since, the papillary and papillary penetrating type of frenal attachment are potentially injurious.

Next, understanding the multitude of etiological factors behind a maxillary midline diastema helps a clinician in identifying a definite cause of MMD and progress accordingly with the treatment. Regarding treatment modalities, various surgical techniques, electrocautery and lasers, offer effective options for frenectomy. However, the timing of intervention still remains a subject of debate among clinicians, with considerations such as the eruption of anterior permanent dentition and the severity of the diastema influencing decision making.

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## References

1. Koora K, Muthu MS, Rathna PV. Spontaneous closure of midline diastema following frenectomy. J Indian Soc Pedod Prev Dent. 2007; 25 (1): 23-6.
2. Suter VG, Heinzmann AE, Grossen J, Sculean A, Bornstein MM. Does the maxillary midline diastema close after frenectomy? Quintessence Int. 2014; 45 (1): 57-66.
3. Tadros S, Ben-Dov T, Cathain EO, Anglin C, April MM. Association between superior labial frenum and maxillary midline diastema A systematic review. Int J Pediatr Otorhinolaryngol. 2022; 32 (1):111-9.
4. Hussein MA, Watted N. Maxillary midline diastema Aetiology and orthodontic treatment-clinical review. IOSR J Dent Med Sci. 2016;15 (6):116-30.
5. Nuvvula S, Ega S, Mallineni SK, Almulhim B, Alassaf A, Alghamdi SA et al. Etiological factors of the midline diastema in children: a systematic review. Int J Gen Med. 2021; 12 (8): 2397-405.
6. Ceremello PJ. The superior labial frenum and the midline diastema and their relation to growth and development of the oral structures Am J Orthod. 1953;39 (2):120-39.
7. Boutsi EA, Tatakis DN. Maxillary labial frenum attachment in children. Int J Paediatr Dent. 2011;21(4):284-8
8. Christabel SL. Prevalence of type of frenal attachment and morphology of frenum in children, Chennai, Tamil Nadu. World J Dent. 2017; 6 (4):203-7
9. Jonathan PT, Thakur H, Galhotra A, Galhotra V, Gupta N. Maxillary labial frenum morphology and midline diastema among 3 to 12- year-old school going children in Sri Ganganagar city: A cross sectional study. J Indian Soc Pedod Prev Dent. 2018; 36 (3): 234-9
10. Pizán ME, Lagravère MO, Villena R. Midline diastema and frenum morphology in the primary dentition. J Dent Child. 2006; 73 (1): 11-4.

11. Dasgupta P, Kamath G, Hs S, Babshet M, Doddamani L. Morphological variations of median maxillary labial frenum: A clinical study. J Stomatol Oral Maxillofac Surg. 2017; 118 (6): 337-41
12. Rajani ER, Biswas PP, Emmatty R. Prevalence of variations in morphology and attachment of maxillary labial frenum in various skeletal patterns A cross-sectional study. J Indian Soc Periodontol. 2018; 22 (3): 257-62.
13. Sewerin IB. Prevalence of variations and anomalies of the upper labial frenum. Acta Odontol Scand. 1971; 29 (4): 487-96.
14. Mirko P, Miroslav S, Lubor M. Significance of the labial frenum attachment in periodontal disease in man. Part 1. Classification and epidemiology of the labial frenum attachment. J Periodontol. 1974; 45 (12): 891-4.
15. Kotlow LA. Oral diagnosis of abnormal frenum attachments in neonates and infants: evaluation and treatment of the maxillary and lingual frenum using the Erbium: YAG laser. J Pediatr Dent Care. 2004;10 (3):11-4.
16. Lioliou E, Kostas A, Zouloumis L. The maxillary labial fraenum: A controversy of oral surgeons vs. orthodontists. Balk J Dent Med. 2012;16 (3):141-6
17. Edwards JG. The diastema, the frenum, the frenectomy: a clinical study. Am J Orthod. 1977; 71 (5): 489-508
18. Elfadel II, Abuaffan AH. Prevalence and etiology of midline diastema among Sudanese University students. Indian J Dent Educ. 2016; 9 (1):15-20.
19. Shashua D, Årtun J. Relapse after orthodontic correction of maxillary median diastema: a follow-up evaluation of consecutive cases. Angle Orthod. 1999; 69 (3): 257-63
20. Harikrishnan R, Nivethigaa B, Ganesh BS. Etiological Factors Of Midline Diastema-A Retrospective Study. Int J Dentistry Oral Sci. 2021; 8 (8): 4119-23.
21. Hasan HS, Al Azzawi AM, Kolemen A. Pattern of distribution and etiologies of Midline diastema among Kurdistan-region Population. J Clin Exp Dent. 2020;12 (10): 938-43.
22. Mumtaz S, Nalbant G, Bölükbaşı EY et al. Novel EDAR mutation in tooth agenesis and variable associated features. Eur J Med Genet. 2020
23. Al Shah J, Dyer F. Current practice for performing labial frenectomies a service evaluation. BOS Clin Eff Bull. 2008; 21 (2): 4- 9.
24. Wheeler B, Carrico CK, Shroff B, Brickhouse T, Laskin DM. Management of the maxillary diastema by various dental specialties. J Oral Maxillofac Surg. 2018; 76 (4): 709-15
25. Baxter RT, Zaghi S, Lashley AP. Safety and efficacy of maxillary labial frenectomy in children: a retrospective comparative cohort study. Int Orthod. 2022; 20 (2):163-9
26. Gujjari SK, Shubhashini PV. Frenectomy: a review with the reports of surgical techniques. Journal of clinical and diagnostic research: J Clin Diagn Res. 2012; 6 (9):1587.
27. Butchibabu K, Koppolu P, Mishra A, Pandey R, Swapna LA, Uppada UK. Evaluation of patient perceptions after labial frenectomy procedure: A comparison of diode laser and scalpel techniques. European J Gen Dent. 2014; 3 (2):129-33
28. Liboon J, Funkhouser W, Terris DJ. A comparison of mucosal incisions made by scalpel, CO2 laser, electrocautery, and constantvoltage electrocautery. Otolaryngol Head Neck Surg. 1997; 116 (3): 379-85.
29. Zaaba NA, Rajasekar A, Kk SS. Evaluation of healing following frenectomy. Bioinformation. 2021;17(12):1138-43

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# Correlation of Biomarkers In the Clinical Study of Accelerated Orthodontics

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## Abstract

This article explores the correlation of biomarkers in clinical studies on accelerated orthodontics, focusing on techniques to reduce treatment time and improve patient comfort. Methods such as Low Level Laser Therapy (LLLT), vibrations, photobiomodulation, and electric current, along with surgical techniques like corticotomy, Periodontally Accelerated Osteogenic Orthodontics (PAOO), micro-osteoperforations, and piezocision, are highlighted for their effectiveness in accelerating orthodontic tooth movement (OTM).

The review underscores the importance of biomarkers such as RANK, OPG, RANKL, interleukins, and matrix metalloproteinases (MMPs) in monitoring bone and periodontal tissue remodeling. A literature search on PubMed, Scopus, Google Scholar, and Web of Science identified 35 relevant articles. Findings show that surgical approaches increase the RANKL, IL-1β, and OPG, enhancing OTM. Physical stimuli like photobiomodulation and electric currents promote collagen turnover, MMP expression, and interleukin levels, while pharmacological methods using cytokines and prostaglandins accelerate OTM through localized injections and gene transfer.

It is concluded that there is a marked increase in biomarker activity while accelerating the orthodontic tooth movement by various methods leading to the alveolar bone remodeling and modeling accompanied by bone formation on the tension side and bone resorption on the compressed side.

## Introduction

Orthodontics aim is to achieve efficient and effective tooth movement, which has driven the development of materials and procedures that enhance patient comfort and shorten treatment time[1]. Tooth movement is facilitated by applying directed forces that induce changes in the bone and periodontal ligament, releasing mediators in gingival crevicular fluid, saliva, and other body fluids[2]. These forces trigger a cascade of cellular and molecular events, conditioning microenvironments to respond to bone bending and tissue remodeling[3].

Osteoclastic activity affects tooth-supporting biomarkers such as RANK, RANKL, and osteoprotegerin (OPG), with OPG inhibiting RANKL-driven osteoclastogenesis. The matrix metalloproteinase (MMP) family also plays a vital role in the remodeling of bone[4]. To hasten the orthodontic tooth movement (OTM), minimally invasive methods like Low Level Laser Therapy (LLLT), vibrations, photobiomodulation, and electric current are favored over invasive techniques like corticotomy. Additionally, pharmacological agents such as Prostaglandin-2, Vitamin D, and Relaxin are employed to enhance tooth movement[5].

## Method

Research publications were searched for 5 months on PubMed, Scopus, Google Scholar and Web of Science, and the articles with the terms accelerated orthodontic, Osteoclastogenesis, Inflammatory markers, Orthodontic tooth movement, RANK, RANKL, OPG. The articles were further analyzed to investigate how biomarkers correlate in clinical studies when accelerating tooth movement using various methods of accelerated orthodontics.

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## Results

Finally,35 articles were collected and they were used to formulate this review

## Discussion

### Biomarkers Of Orthodontic Tooth Movement

A biomarker is a substance that can be used to monitor and quantitatively assess pathogenic processes, normal physiological processes, or pharmacological responses to therapeutic interventions. An ideal biomarker should be sensitive, specific, and capable of providing information about the biological state, particularly regarding changes in periodontal tissue and their relation to specific stages of orthodontic tooth movement (OTM). Understanding the cellular processes involved helps determine the appropriate mechanical loading, thereby minimizing the treatment period and potentially avoiding side effects from orthodontic therapy[6].

### Accelerated Orthodontic

It refers to a technique that speeds up tooth movement without adverse effects, accomplished through surgical, physical, or pharmacological approaches.

### Accelerating Tooth Movement By Surgical Approaches

Surgical interventions in orthodontics have become notable for their ability to accelerate tooth movement while maintaining treatment effectiveness and patient safety.

The various methods used are,

- Corticotomy
- PAOO
- Microosteoperforations (Mops)
- Piezocision

**1. Corticotomies**

Kawakami et al.[7] performed a study on histological responses at the corticotomy site, observing increased remodeling of bone cells, widened sutures, and irregular cell and fiber arrangement. According to the study conducted by Wang et al.[8], corticotomy induced acceleration of osteoporosis occurs at the cellular level by promoting infiltration of macrophage via the JAK/STAT3 and NF-κB pathways during the early and late phases.

**2. Periodontally Accelerated Osteogenic Orthodontics( PAOO )**

Periodontally Accelerated Osteogenic Orthodontics (PAOO) is a type of treatment method that integrates selective alveolar corticotomy, orthodontic force application, and particulate bone grafting. According to a study conducted by Jiaqi Wu et al.[9] which explored protein changes in GCF at various moments after PAOO using proteomics methods to identify significant bone metabolization related biomarkers, the authors found a total of one thirty four proteins selected based on keywords such as osteoblast markers, osteoclastogenesis, regulating genes, osteoclast markers and inflammatory markers. Among these, 5 proteins identified through label free quantitative proteomics were KLF10, FBN1, APOA1, SYT7, and NOTCH1. The study noted a rapid increase in NOTCH1 levels within the first two weeks after PAOO, followed by a slower growth trend.

**3. Micro-osteoperforation**

Micro-osteoperforation is an efficient, comfortable, and safe procedure that accelerate the movement of tooth and reduces the duration of treatment significantly. Alikani et al.[10]( Fig 1) found in their clinical study that osteoclast activity is crucial in regulating bone resorption, impacting the speed of tooth movement. Orthodontic forces usually trigger increased inflammatory markers, like chemokines and cytokines, which are vital for recruiting precursor cells for osteoclasts and aiding in their differentiation into mature osteoclasts. Their study concluded that micro-osteoperforations increased tooth movement rates by 2.3 times, accompanied by a notable rise in inflammatory marker levels.

A similar study conducted by Raghav P et al.[11] (Fig 2,) assessed the impact of micro-osteoperforations (MOPs) on canine retraction rates and biomarker expression in gingival crevicular fluid (GCF). The results of this study showed a significant difference in canine retraction rates only during the initial 4 weeks, with no significant difference observed from weeks 8 to 16 between the MOPs and control groups. Additionally, there was a notable increase in alkaline and acid phosphatase activity in GCF during the first 4 weeks of retraction of canine in the MOPs group in contrast to the control, indicating increased biomarker activity during the initial treatment period.

**4. Piezocision**

Piezocision, is a surgical procedure that is minimally invasive, and has been utilized to hasten tooth movement. Yildirim et al.[12] performed a study to assess GCF levels of osteocalcin (OC) and type I collagen cross-linked C-terminal telopeptide during canine distalization without and with piezocision . They found that GCF OC levels on the compression side and ICTP levels on the tension side were lower in the piezocision group .

Additionally, Fernandes T et al.[13] evaluated the impact of piezocision (PZ) in hastening maxillary canine retraction and its impact on various remodeling of bone markers in GCF. Their analysis revealed higher IL-1β levels at the 2nd and 12th weeks, with no significant differences in TNF-α expression between the experimental and control groups. OPG levels were elevated on the experimental side at the 2nd and 12th weeks, while RANKL levels were more on the experimental side. Furthermore, DKK1 levels on the experimental side were reduced at the 4thweek in this clinical study.

### Accelerating Tooth Movement By Physical Stimuli

**1. Direct Electric Currents and Pulsed Electromagnetic Fields**

In 1987, Stark and Sinclair[14]conducted a study examining the impact of pulsed electromagnetic fields on pigs, using the piezoelectric theory. Their findings revealed a nearly doubled rate of movement (tooth) ($0.42 \pm 0.17$mm) compared to the control group ($0.28 \pm 0.08$mm), indicating enhanced protein metabolism in the study group. They also noted notable elevation in the quantity of osteoclasts and elevated levels of creatinine uric acid, along with creatinine phosphokinase.

Similarly, Spadari et al.[15] found that stimulation of electrical current (10μA/5 min) combined with force application improved tissue responses. This combination modulated the expression of TGF- β1, bFGF , and VEGF while also affecting the quantity of granulocytes, blood vessels, fibroblasts, and osteoclasts. However, despite the positive correlation between stimulation of electrical current and accelerated OTM, further research involving human participants is recommended for a more conclusive outcome. This suggestion comes from a meta-analysis and systematic review by Dutta et al.[16] on the application of stimulation of electrical current in accelerated orthodontics.

**2. Vibratory Stimulus**

Krishtab et al. [17] pioneered the utilization of vibratory stimulation to accelerate tooth movement, marking a significant advancement in the field. Building on this foundation, Ohmae et al.[18] further refined the technique by introducing ultrasonic vibration, which effectively enhanced the rate of tooth movement. Nishimura et al.[19] invented a vibration incorporated system with a specific frequency (sixty one ± 8.375Hz), applied to male Wistar rats' maxillary molars, owing to the notable increase in tooth movement rate. The group which is treated exhibited an increase in the presence of osteoclasts when compared with the control group, indicating the effectiveness of vibrational stimulation. The elevated RANKL expression in the resonance vibration group is disclosed by immunohistochemistry analysis, suggesting improved osteoclast survival, function, and generation.

Chatmahamongko et al. [20] compared the quantity of OPG, RANKL, IL-6, and Il61β in compressed human alveolar bone osteoblasts subjected to vibratory stimuli with a control that didn't receive vibration. They found nothing significant in expression between the experimental and control groups.

**3. Photobiomodulation**

To stimulate or inhibit biological activities with light energy at particular intensities, wavelengths, and irradiation regimens is known as photobiomodulation.

**Low level laser therapy**

Low level laser therapy (LLLT) is a focal point for its role in hastening tooth movement and supporting the remodeling of bone processes. Studies employing LLLT in animal models have consistently demonstrated notable improvements in tooth movement speed, often accompanied by positive changes in osteoblastic and osteoclastic activities within bone tissue. Notably, Kawasaki and Shimizu [21] observed a significant 1.3 times increase in speed of tooth movement, along with heightened osteoclast and osteoblast activity during the remodeling of bone in a rat model.

However, research by Limpanichkul et al. [22] involving 12 young adult patients found no substantial differences in tooth movement with a comparison of the experimental group and control group over a III month period. This outcome was attributed to the relatively low dosage of LLLT administered (25 J/cm2). Additionally, it was noted that irradiation with laser stimulates osteoclastogenesis and enhances remodeling of bone by activating the pathway of M-CSF/c-fms, as concluded by Fujita et al.[23].

Various molecules are identified in the process of low level laser induced acceleration of tooth movement. These include increased turnover of collagen type- I and fibronectin (Kim et al.,[24]), elevated expression of cathepsin K, MMP-9, and alpha (v) beta (3) integrins (Yamaguchi et al.,[25]), and statistically significant rise in the quantity of OPG and RANKL in the GCF (Dominiquez et al.,[26]). Moreover, higher levels of interleukins have been linked to increased remodeling of bone induced by orthodontic treatment forces in recent laser irradiation studies (Varella et al., , Fernandes et al., 27).

**Light emitting diode (LED) therapy**

Research exploring the efficacy of light emitting diode (LED) therapy has primarily focused on its ability to expedite tooth movement and improve orthodontic outcomes. LED therapy functions by delivering specific light wavelengths to targeted areas, stimulating cellular activity, and encouraging tissue regeneration. This area of study has yielded promising findings, with several studies indicating faster tooth movement and reduced treatment durations when incorporating LED therapy into orthodontic protocols.

Studies in rats using LED mediated photobiomodulation therapy found reduced root resorption (Ekizer et al.,[28]) and quicker resolution of crowding (Kau et al.,[29]). Fernandes et al.[27] describe the velocity of intrusion of 0.26 mm/month in the irradiated group compared to 0.17 mm/month in the group that is not irradiated over an eight month period. Additionally, there was a significant increase in cytokine levels in the photobiomodulation group compared to the group of control , indicating a positive impact of LED therapy on cytokine activity.

Shankar et al.[30] conducted an study assessing GCF, prostaglandin-E2 (PGE-2) and interleukin 1-beta (Il1-β) levels, after the placement of elastic separators without or with low level laser therapy(). Their findings indicated that low level laser therapy reduced inflammatory markers like prostaglandin-E2 (PGE-2) and interleukin 1-beta (Il1-β) in patients using separators, suggesting an association between biomarkers and laser treatment.

**Accelerating Tooth Movement Pharmacological Approaches**

**Local Cytokine Delivery**

Cytokines, which are signaling proteins found extracellularly, play crucial roles in inflammation and remodeling of bone, both vital processes for osteogenesis malformation (OTM). Krishnan and Davisovitch[2] highlight that cytokines also support the development, activation, and death of periodontal ligament (PDL) cells. This assertion is reinforced by heightened cytokine levels during tooth movement, including TNF-α, interleukins, and RANKL. Moreover, interleukin activities are influenced by increased production of macrophage colony-stimulating factor and PGE2, which promote osteoclast development.

Research by Saito et al.[31] illustrated that cells can respond to multiple stimuli simultaneously. In experiments without the cytokine IL-1β (as a control group), fibroblasts released minimal PGE2 into the incubation media. However, the existence of IL-1β significantly increased prostaglandin E2 (PGE2) production in these cells[32].

**Prostaglandins (Pgs)**

Prostaglandins (PGs), a type of lipid, are not stored within cells but are enzymatically produced in the cell membrane from fatty acids by cyclooxygenase (COX) enzymes. Klein and Raisz demonstrated in 1970 that PGs induce osteoclastic hyperplasia, showcasing their bone resorbing capabilities.

In a study by Lee[33], after administering PGE1, a histological examination of paradental tissues revealed osteoclast appearance within six hours of force application, peaking within three days. Brudvik and Rygh discovered a potential downside in rats following local PGE2 injection, indicating a propensity for root resorption. Leiker et al. observed that a single PGE2 injection (at low doses of 0.1–1.0μg) significantly accelerated tooth movement, with repeated injections showing minimal impact.

Patil et al. performed a clinical study on 15 patients using a small dose of 1.0 μg PGE1 combined with lignocaine to reduce pain. They found a notable increase (1.7:1) in distal canine retraction rate, consistent with Yamasaki et al.[34] Follow-up radiographs did not show root resorption evidence. Eltimamy et al. noted conflicting evidence on tooth movement acceleration with prostaglandins, while Spoerri et al. found no association of prostaglandin injections on root resorption.

**RANKL**

RANKL is a type of cytokine that regulates the function and formation, the cells responsible for bone resorption, and survival of osteoclasts. RANKL is essential for optimal bone metabolism.

The study conducted by Kanzaki et al[35]. , Li et al. found that increased osteoclastic activity by locally injecting the RANKL.

## Conclusion

Biomarkers are pivotal in accelerated orthodontics, impacting tooth movement rates and overall treatment success. Surgical, physical, and pharmacological methods showcase distinct interactions with biomarkers, influencing tooth movement rates and remodeling of bone.

- In surgical methods of accelerating tooth movement, the study of biomarker levels in the GCF shown that RANKL levels, IL-1β levels, and OPG levels were higher on the experimental side whereas TNF-α expression didn't show significant differences and DKK1 levels were lower.
- In physical stimulus for accelerating the movement of the tooth, many other molecules have been identified such as increased turnover of collagen type I and fibronectin, increased cathepsin K, expression of MMP-9, and αVβ3 and even statistically significant increases in the release of OPG and RANKL in the GCF.
- In photobiomodulation, greater levels of interleukins (IL-8, IL-6, and IL-1β) have been associated twith greater remodeling of bone brought on by orthodontic forces.
- Electrical stimulation enhanced tissue responses, modulating the expression of VEFG, TGFβ1, and bFGF while decreasing the quantity of granulocytes and increasing the quantity of fibroblasts, blood vessels, and osteoclasts.
- In the low level vibratory method, significant differences in the expression of RANKL, OPG, IL6, and Il-1β were not seen.

In the pharmacological methods, either done by a local gene transfer or local injection, all the various methods aimed at release of agents that are injected over a time period, inducing reaction of inflammatoin or expression of protein respectively.

Overall, integrating biomarker analysis into clinical studies of accelerated orthodontics holds great promise for advancing treatment protocols, improving patient outcomes, and ultimately transforming the landscape of orthodontic care.

## Reference


1. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials. SeminOrthod. 1997; 3 (3): 166-77.
2. Krishnan V, Davidovitch ZE. Cellular, molecular, and tissue-level reactions to orthodontic force. Am J Orthod Dento-facial Orthop. 2006;129 (4): 469-72.
3. Erdur EA, Karakaslı K, Oncu E, Ozturk B, Hakkı S. Effect of injectable platelet-richfibrin (i-PRF) on the rate of tooth movement: A randomized clinical trial. Angle Orthod. 2021; 91 (3): 285-92
4. Kumar AA, Saravanan K, Kohila K, Kumar SS. Biomarkers in orthodontic tooth movement. J Pharm Bioallied Sci. 2015; 7 (2): 325-30.
5. Meikle MC. The tissue, cellular, and molecular regulation of orthodontic tooth movement: 100 years after Carl Sand-stedt. Eur J Orthod. 2006; 28 (3): 221-40.
6. Taba M, Kinney J, Kim AS, Giannobile WV. Diagnostic biomarkers for oral and periodontal diseases. Dental Clinics. 2005; 49 (3): 551-71.
7. Kawakami T, Nishimoto M, Matsuda Y, Deguchi T, Eda S. Histological suture changes following retraction of the maxillary anterior bone segment after corticotomy. Endod Dent Traumatol. 1996;12 (1):38-43.
8. Wang Y, Zhang H, Sun W, Wang S, Zhang S, Zhu L et. al. Macrophages mediate corticotomy accelerated ortho-dontic tooth movement. Sci Res. 2018; 8 (1):1678-80.
9. Wu J, Xu L, Li C, Wang X, Jiang J. Exploration of key factors in Gingival Crevicular fluids from patients undergoing Periodontally Accelerated Osteogenic Orthodontics (PAOO) using proteome analysis. BMC Oral Health. 2023; 23 (1): 934-43.
10. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, et al. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofacial Orthop. 2013;144 (5): 639-48.
11. Raghav P, Khera AK, Preeti P, Jain S, Mohan S, Tiwari A. Effect of micro-osteoperforations on the rate of orthodontic tooth movement and expression of biomarkers: a randomized controlled

clinical trial. Dental Press J Orthod. 2022; 27 (2):221-34.
12. Yildrum HS, Ates M, Gun IO, Kuru B, Cakirer B, Kuru LE. Osteocalcin and Cross-Linked C-Terminal Telopeptide of Type I Collagen in Gingival Crevicular Fluid during Piezocision Accelerated Orthodontic Tooth Movement: A Randomized Split-Mouth Study. Niger J Clin Pract. 2023 ; 26 (4): 470-7.
13. Fernandes LS, Figueiredo DS, Oliveira DD, Houara RG, Rody WJ, Krishta canine retraction : a randomized controlled clinical trial. Prog Orthod. 2021; 22 (2):1-1.
14. Stark TM, Sinclair PM. Effect of pulsed electromagnetic fields on orthodontic tooth movement. Am J Orthod Dentofacial Orthop. 1987; 91(2): 91-104.
15. Spadari GS, Zaniboni E, Vedovello SA, Santamaria MP, do Amaral ME, Dos Santos GM, Esquisatto MA, Mendonca FA, Santamaria-Jr M. Electrical stimulation enhances tissue reorganization during orthodontic tooth movement in rats. Clin Oral Invest. 2017; 21(1):111-20.
16. Dutta S, Rout T, Patil AS, Deshmukh S. Use of electrical stimulation for accelerated orthodontics in humans: a systematic review and meta-analysis. Evid Based Dent. 2024; 45 (1):1-9.
17. Krishtab, S.I., Doroshenko, S.I. and Liutik, G.I. (1986) Use of vibratory action on the teeth to accelerate orthodontic treatment. Stomatologiia( Mosk)1986; 65 (2): 61-63.
18. Ohamae, ,M., Saito, S., Morohashi, T. et al. (2001) Biomechanical acceleration of experimental tooth movement by ultrasonic vibration in vivo part 1 : homo directional application of ultrasonication to orthodontic force. Orthod Waves 2001;60(2):201-212.
19. Nishimura M, Chiba M, Ohashi T, Sato M, Shimizu Y, Igarashi K, et al. Periodontal tissue activation by vibration: intermittent stimulation by resonance vibration accelerates experimental tooth movement in rats. Am J Orthod Dentofacial Orthop. 2008; 133 (4): 572-83.
20. Chatmahamongkol C, Pravitharangul A, Suttapreyasri S, Leethanakul C. The effect of compressive force combined with mechanical vibration on human alveolar bone osteoblasts. J Oral Biol Craniofac Res. 2019; 9 (1): 81-5.
21. Kawasaki K, Shimizu N. Effects of low energy laser irradiation on bone remodeling during experimental tooth movement in rats. Lasers in Surgery and Medicine: Laser Surg Med. 2000; 26 (3): 282-91
22. Limpanichkul W, Godfrey K, Srisuk N, Rattanayatikul C. Effects of low level laser therapy on the rate of orthodontic tooth movement. OrthodCraniofac Res. 2006;9(1):38-43.
23. Fujita S, Yamaguchi M , Utsunomiya T , Yamamoto H, Kasai K. Low energy laser stimulates tooth movement velocity via expression of RANK and RANKL. OrthodCraniofac. Res.2008;11(3):143-55.
24. Kim YD, Kim SS, Kim SJ, Kwon DW, Jeon ES, Son WS. Low-level laser irradiation facilitates fibronectin and collagen type I turnover during tooth movement in rats. Lasers Med Sci. 2010; 25 (2): 25-31.
25. Yamaguchi M, Hayashi M, Fujita S, Yoshida T, Utsunomiya T, Yamamoto H, Kasai K. Low-energy laser irradiation facilitates the velocity of tooth movement and the expressions of matrix metalloproteinase-9, cathepsin K, and alpha (v) beta (3) integrin in rats. Eur J Orthod. 2010; 32 (2):131-9.
26. Domínguez A, Gómez C, Palma JC. Effects of low level laser therapy on orthodontics: rate of tooth movement, pain, and release of RANKL and OPG in GCF. Lasers Med Sci. 2015; 30 (1): 915-23.
27. Fernandes MR, Suzuki SS, Suzuki H, Martinez EF, Garcez AS. Photobiomodulation increases intrusion tooth movement and modulates IL6, IL8 and IL-1β expression during orthodontically bone remodeling. J Bio photonics. 2019;12(10):201-22.
28. Ekizer A, Uysal T, Güray E, Akkuș D. Effect of LED-mediated-photobiomodulation therapy on orthodontic tooth movement and root resorption in rats. Lasers Med Sci. 2015;30 (2):779-85.
29. Kau CH, Kantarci A, Shaughnessy T, Vachiramon A, Santiwong P, de la Fuente A et. al. Photobiomodulation accelerates orthodontic alignment in the early phase of treatment. Prog Orthod. 2013;14 (1):1-9.
30. Shankar S, Shetty SV, Nayak RS, Tewari N, Javed A. In vivo study of gingival crevicular fluid interleukin 1-beta (Il1-β) and prostaglandin-E2 (PGE-2) levels with pain perception after placement of elastomeric separators with and without low level laser therapy: An in vivo study. IP Indian J Orthod Dentofacial Res. 2023: 9 (4): 258-269.
31. Saito S, Dr. Rosol TJ, Saito M, Ngan PW, Shanfeld J, Davidovitch Z. Bone resorbing activity and prostaglandin E produced by human periodontal ligament cells in vitro. J Bone Miner Res. 1990; 5 (10): 1013-8.
32. Grieve III WG, Johnson GK, Moore RN, Reinhardt RA, DuBois LM. Prostaglandin E (PGE) and interleukin-1β (IL-1β) levels in gingival crevicular fluid during human orthodontic tooth movement. Am J Orthod Dentofacial Orthop. 1994;105 (4): 369-74.
33. Lee W. Experimental study of the effect of prostaglandin administration on tooth movement with particular emphasis on the relationship to the method of PGE1 administration. Am J Orthod Dentofacial Orthop. 1990; 98 (3): 231-41.
34. Yamasaki K, Shibata Y, Imai S, Tani Y, Shibasaki Y, Fukuhara T. Clinical application of prostaglandin E1 (PGE1) upon orthodontic tooth movement. Am J Orthod Dentofacial Orthop. 1984; 85 (6): 508-18.
35. Kanzaki, H., Chiba , M., Arai, K.et al. Local RANKL gene transfer to the periodontal tissue accelerates orthodontic tooth movement. Gene Ther. 2006;13 (1): 678-85.

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# Asymmetric Extraction Decision In Orthodontic Treatment: A Literature Review

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## Abstract

**Introduction:** In spite of the successful case reports published, asymmetric extractions are still seen with skeptical eyes. Material and methods: Several keywords (asymmetric, treatment, orthodontics, extraction, mechanics) were searched in English using End Note 9 software to locate studies in the PubMed, Web of Science (WSC), and LILACS databases.
**Results:** 38 articles were selected for discussion.
Case selection should top the priority list for successful treatment with asymmetric extraction. Hence, a few indications which may help the reader with the decision of extraction depending on the malocclusion being treated, ranging from subdivision to Bolton discrepancy cases, are clarified.
**Keywords:** Asymmetric Extraction, Case Selection, Subdivision, Premolar Extraction, Incisor Extraction.

## Introduction

The domain of orthodontics is a multifactorial discipline dedicated to enhance the alignment and harmony of dental structures working towards a more symmetric oral cavity. Among the array of techniques employed by orthodontists to achieve this, asymmetric extractions stand as a distinctive and sometimes controversial approach. Controversial because it can be perceived as rather odd that the symmetry that we are perpetually running after can, in reality, also be achieved by asymmetric means.

Furthermore, hindsight has enabled specialists to understand that the maintenance of all dental units to achieve the goals of harmony and stability is not always possible, nor is it always desirable.[1] So, just as a force is best confronted with a force of the same nature, asymmetric extractions can act as a saving grace when dealing with asymmetries in the dentition which pose as a clinical challenge.

The journey towards effective treatment of asymmetry begins by identifying the underlying cause of the imbalance, whether it stems from skeletal or dental issues, and to discern the specific factors contributing to it. Situations where asymmetric extraction may act as a saviour might be asymmetries under genetic and/or environmental influences; the genetically asymmetric cases may comprise skeletal asymmetry, certain malocclusions, severe tooth shape anomalies, tooth size arch length discrepancy and congenitally missing tooth. Whereas dental asymmetry, Class II subdivision malocclusions, favourable unilateral movement of posterior teeth, increased overjet and overbite corrections may come under environmental asymmetry.[2] Once diagnosed, the treatment planning phase necessitates a careful evaluation of the severity of the dissymmetry to tailor an appropriate treatment plan, drawing upon a range of extraction patterns; ranging from 3 premolar extraction to unilateral molar extraction in the posterior to single mandibular incisor or impacted/malposed canine in the anterior as per the requirement of the case.

We, as orthodontists, have come a long way from Father Angle's non extraction approach to the day when the then pioneers of our branch roared and blatantly rejected Tweed's invention of extraction in the

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meeting of the Angle Society in Chicago back in 1940 to ultimately today where we can find innumerable researches, reports and reviews on asymmetric extractions. But still, a controversy in the literature exists regarding the choice of the tooth to be extracted and the post-treatment stability. Thus, there is a need to further explore case selection, treatment planning and outcomes concerning asymmetric extractions.

## Materials and Methods

Several keywords (asymmetric, treatment, orthodontics, extraction, mechanics) were searched in English using End Note 9 software to locate studies in the PubMed, Web of Science (WSC), and LILACS databases. These keywords had to be present in the title, keywords, abstract, or text of the articles. Papers were chosen based on specific inclusion and exclusion criteria. Studies involving orthognathic surgery, syndromes, systemic diseases, cleft palate, orthognathic surgery, and conventional extractions of first premolars were excluded. Articles pertaining to case reports, original research, and case control studies that involved the mechanical or asymmetric extraction of permanent teeth were handpicked.

## Results

Finally, 38 articles were selected for discussion.

## Discussion

Necessity is the mother of invention i.e. when the need for something becomes essential, one is forced to find ways of achieving it and asymmetric extractions work in a very similar fashion while dealing with asymmetric arches.

Lundstrom[2] eloquently articulated that perfect mirror-image similarity, in a mathematical sense, is an improbability among living organisms; therefore, bilateral symmetry exists more as an abstract concept in biology. This principle generally holds when considering populations at large but rarely applies to an individual entity. He further went on to classify asymmetry according to an orthodontic point of view as

- **Quantitative Asymmetry:** of the type that is either fully present or not present at all (for instance; absence of teeth or presence of supernumerary teeth)
- **Qualitative Asymmetry:** With a progressive shift from the least to the most amount of asymmetry that the specific part can exhibit

Furthermore, he pointed out how significant a role external environmental factors, such as uneven chewing, finger sucking habits, decay leading to loss of contact points, early removal of deciduous or permanent teeth and trauma, play to bring about the discrepancy between right and left sides, aside from genetic influences.[2]

A few common indications or situations where asymmetric extractions enter the equation are while handling asymmetries in the oral cavity concerning midline deviation, missing teeth, subdivision cases, impacted cases involving only one side of the arch, unilateral cross bites, deviation in the arch form, alteration in the morphology of teeth, etc.[3] There are additional criteria which need to be considered while reaching towards this unorthodox extraction treatment plan.

## Different Asymmetric Extraction Protocols

### I. Class II Malocclusion

The removal of the upper first premolar accompanied by lower second premolar is an effective treatment alternative for patients having class II malocclusions with slight crowding and/or proclined lower incisors.

To treat the proclined upper incisors and to correct any minimal crowding/proclination in the lower incisors, this method is preferred since it has little to no facial impact as anchorage loss in the mandible is required to achieve a class I molar relation i.e. group C anchorage.

This method is the preferred choice for treating proclined upper incisors and correcting any minimal crowding/ proclination in the lower incisors since it has nominal facial impact because anchorage loss in the mandible is necessary to achieve a class I molar relation, also known as group C anchorage.

When combined with a facebow or a trans-palatal arch, class II elastics may facilitate this process and at the same time preserve maxillary anchorage. If there is a misalignment in the arch, it is reasonable to remove the first bicuspid located on one side and the second bicuspid on the opposite side.

### II. Class II Subdivision with Mandibular Midline Deviation

The uneven extraction protocol of three premolars; two upper bicuspids and one lower bicuspid (opposite to midline deviation) is usually indicated in Type 1 Class II subdivision malocclusion treatment. Such an approach offers more straightforward mechanics and enhances the likelihood of successful occlusal treatment outcomes relative to the extraction of four premolars, minimizing the retraction of the mandibular incisors and the supporting soft tissue. Together with the coincidence of upper and lower dental midlines, it typically results in Class I canine and molar relations on the Class I side and the Class II side sees a Class II molar and Class I canine relationship.

Whereas, the other treatment alternative i.e. to go for all four symmetrical premolar extraction would've not only been more difficult to achieve since molar mesialization is more challenging biomechanically, but also painstaking for the patient as this would've increased the treatment time and automatically resulted in increased duration of elastic wear.

Treatment by extraction of three premolars in Class II subdivision cases requires reduced treatment time and yields more desirable outcomes.[4] Janson et al[5] also that this uneven extraction protocol is the most effective in causing minimal changes to the profile. However, the authors noted that using a three premolar extraction protocol can result in extrusion of lower incisors and asserted that symmetrical extractions provide superior vertical control of the anterior teeth. They also deduced that an asymmetrical positioning of the first permanent molars is an unavoidable outcome in such scenarios. This observation was similarly corroborated by the findings of Johnson and Smith.[6]

**III. Class II Subdivision with Maxillary Midline Deviation**

An alternative form of asymmetric extraction therapy thatmight be of help in Class II subdivision (type 2) cases is the extraction of only one premolar[7]. Premolar of Class II maxillary quadrant is extracted to correct midline deviation and at the same time finishing the case in Class I canine relation. This would greatly aid in the treatment of a mandibular curve that does not need extractions and at the same time help relieve midline deviation with minimal alterations to facial appearance

**IV. Class III Subdivision with Mandibular Midline Deviation**

In patients with Class III subdivision malocclusions and a straight profile, it is recommended to extract the lower first molar on the Class III side. This is followed by correction midline deviation and reverse overjet, by distalizing the teeth in front of the extracted molar i.e. retracting premolar and canines and protracting the second molar to achieve a Class I molar relationship. For mild class III cases, edge to edge bite can be corrected by single mandibular incisor extraction

## Bolton Discrepancy Cases

A Class I malocclusion, characterized by a notable excess in the size of mandibular teeth, is often addressed by removing one lower incisor. A mandibular tooth-size excess over 1.6 mm, as identified by the Bolton analysis, is considered significant and can usually be addressed through one of three methods: interproximal reduction, extraction, or restoration. Typically, extraction of a mandibular incisor is performed in cases where Bolton discrepancies are greater than 2.0 mm.

Also, according to Riedel et al[8], when there is more mandibular anterior tooth material than maxillary anteriors, mandibular incisor extractions are advised. Nevertheless, the decision to extract should not be undertaken solely based on Bolton's tooth size discrepancy but also be supported by proper diagnostic wax set-up accompanied by clinical experience. Furthermore, considerations like the morphology of the maxillary incisor crowns and the amount of interproximal enamel must also be taken into account when planning treatment.

If asymmetric extraction is a controversial topic, then mandibular incisor extraction can probably be, if not more, than halfway be responsible for it. Gingival recessions, black triangles, tooth size discrepancy, space reopening, midline deviations, increased overjet and overbite[9] are only a few of the many disputes the orthodontist needs to be answerable about.

Levii[10] states that there is one thing that is certain i.e. when forced to, one can successfully treat a three incisor case. Therefore, we should draw from this experience and deliberately apply the procedure in treating specific malocclusions.

Gísli Vilhjalmsson et al.[11] developed a two step preparation of extraction site to address the issue of black triangles after lower single incisor extraction. First, the incisor to be removed is orthodontically tipped lingually to a safer location. Then, most of the space in front of it is closed before the extraction. This method shifts the new extraction site away from the delicate crestal bone, preserving the height of the alveolar crest at the tooth's original location. This method also takes into consideration potential patient worries regarding the aesthetic impact of extracting a tooth located at the front.

Non-extraction treatment in cases of dental crowding is commonly believed to result in relapse after retention is removed. Reidel[8] proposed that, for patients with significantly crowded lower dental arches, extracting one or more mandibular incisors is the only sensible alternative. This approach can enhance the stability of the lower front teeth area without the need for continuous retention.

Finally, several clinical situations have been identified that can be effectively treated with mandibular incisor extraction choice. These include mild to moderate Class III malocclusion, edge to edge anterior occlusion or anterior crossbite, mild anterior mandibular tooth size excess (such as with upper peg-shaped laterals or missing upper lateral incisors), crowded lower incisors with mild to no crowding in the upper arch, an acceptable soft tissue profile, minimal to no growth potential, and minimal open bite tendencies.[12]

## Conclusion

Asymmetric extraction can effectively address a wide range of malocclusions, inclusive of:

- Class II malocclusion
- Type 1 and 2 Class II subdivision malocclusions
- Class III subdivision malocclusion
- Class III malocclusion
- Bolton Discrepancy cases

In subdivision cases, the asymmetric extraction approach may help in achieving class I canine relation with coinciding midlines. But at the same time, one needs to keep in mind that not many facial changes would be achieved. In cases of Bolton discrepancy, extracting a lower incisor should be considered as a treatment option. Class III subdivisions can be dealt with single mandibular molar extraction as long as the patient has a straight profile. However, the orthodontist must be in full control of the mechanics to ensure the best possible results at the end of the treatment.

Moreover, asymmetric extraction offers several advantages over traditional symmetrical extraction protocols. Some of them are:

- Reduced treatment time due to less extraction space created.
- Reduced requirement of patient cooperation due to less elastic wear time.
- Better correction of midline deviation seen in subdivision cases.
- Better retention is seen due to minimal changes in intercanine width.
- Psychological benefit for the patient by undergoing lesser extractions and thus preserving dental structures cannot be overlooked.

Hence, asymmetric extraction represents a valuable adjunctive tool in the orthodontic armamentarium for the management of dental asymmetries and malocclusions.

## Disclosures

The authors do not have any conflict of interest to declare.

## References


1. Tayer BH. The asymmetric extraction decision. Angle Orthod. 1992; 62 (4): 291-7.
2. Lundström A. Some asymmetries of the dental arches, jaws, and skull, and their etiological significance. Am J Orthod. 1961; 47 (2): 8-106.
3. Shetty S, Kumar A. Unusual extraction combinations in orthodontics A literature review. Int J Oral Health Dent. 2020; 6 (3):193-6.
4. Baxi S, Bhatia V, Tripathi AA, Kumar P, Pandey A, Taide PD, Tripathi A. Asymmetric Extraction Decision in Orthodontics. Cureus. 2023;15 (6): 54-9.
5. Janson G, Carvalho PE, Cançado RH, de Freitas MR, Henriques JF. Cephalometric evaluation of symmetric and asymmetric extraction treatment for patients with Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop. 2007;132 (1): 28 35.
6. Johnson DK, Smith RJ. Smile esthetics after orthodontic treatment with and without extraction of four first premolars. Am J Orthod Dentofacial Orthop. 1995; 108 (2): 162-7.
7. Janson G, Araki J, Estelita S, Camardella LT. Stability of class II subdivision malocclusion treatment with 3 and 4 premolar extractions. Prog Orthod. 2014;15 (1):1-6
8. Riedel RA, Little RM, Bui TD. Mandibular incisor extraction-post retention evaluation of stability and relapse. Angle Orthod. 1992; 62 (2):103-16.
9. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod. 1958; 28 (3):113-30.
10. Levin S. An indication for the three incisors case. Angle Orthod. 1964; 34 (1):16-24.
11. Vilhjálmsson G, Zermeno JP, Proffit WR. Orthodontic treatment with removal of one mandibular incisor: Outcome data and the importance of extraction site preparation. Am J Orthod Dentofacial Orthop. 2019;156 (4): 453-63.
12. Zhylich D, Suri S. Mandibular incisor extraction: a systematic review of an uncommon extraction choice in orthodontic treatment. J Orthod. 2011; 38 (3):185-95.

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# Anatomical Insights In Orthodontic Bone Screw Placement: A Review

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## Abstract

In today's scenario, treatment approaches have been changed to treat complex cases. Traditionally, cases which were treated by extraction only or by surgical approach to achieve acceptable incisor position, now these can be done by new advancements of orthodontic bone screws (infra zygomatic crest screw and buccal shelf screw). These screws provide sufficient anchorage for en mass distalization and intrusion. This narrative review article aims to provide anatomical factors needs to be considered for placing these extra alveolar TADs to achieve maximal stability so that they can serve for the purpose they are being used.

**Keywords:** Anchorage, Bone screws, infrazygomatic crest screw, buccal shelf screws

## Introduction

Orthodontics, dedicated to the precise alignment of teeth and the correction of malocclusions, continues to evolve with the introduction of innovative treatment techniques and technologies. Kanomi[1] in 1997 introduced surgical miniscrews for orthodontic anchorage. Proper insertion at a safe site plays a crucial role in achieving primary stability of these mini-screws. Two noteworthy advancements within the realm of extra-alveolar bone screws (EABs) are infrazygomatic screws (IZCs) and Mandibular buccal shelf screws (MBS). These specialized orthodontic implants have garnered attention for their unique applications in addressing complex clinical scenarios and facilitating precise tooth movements. These screws provide absolute anchorage in distalization and intrusion after attaining primary stability with in the bone by osseointegration. IZCs are placed in infrazygomatic region of bone and MBSs are placed in buccal shelf area of mandible. These region provide primary stability to the screws due to their superior bone quality. Anatomically, stability of IZCs depends upon angulation at which screw is inserted, bone quality (bone thickness, bone depth, bone density) and maxillary sinus proximity. Stability of MBSs also depends upon angulation with long axis of tooth, bone depth, thickness and proximity to inferior alveolar nerve, clearance from roots and growth pattern of mandible. These screws offer additional anchorage points for orthodontic forces and can be instrumental in facilitating challenging tooth movements, especially in situations where traditional anchorage methods may be insufficient. The use of these advanced anchorage devices represents a significant step forward in orthodontics, offering practitioners greater precision, control, and treatment flexibility. By reducing the reliance on neighbouring teeth for anchorage and mitigating the need for more invasive procedures, these screws contribute to shorter treatment times and improved patient comfort. However, as with any innovative technique or device, understanding both the potential benefits and challenges is crucial for orthodontists, researchers, and dental professionals. This narrative review aims to provide a comprehensive resource for those looking to gain insights into the anatomic considerations associated with infrazygomatic and buccal shelf screws in orthodontics, ultimately contributing to the continued advancement of this dynamic field.

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### Anatomy of Infra zygomatic Crest Area

Infrazygomatic screws are a subset of extra-alveolar bone screws that are inserted above the zygomatic bone, a part of the facial skeleton, to provide anchorage for orthodontic purposes. IZC is a bony ridge within the maxilla extending lateral to the roots of the first and second maxillary molars from the buccal cortical plate. Superiorly, it reaches up to the zygomaticomaxillary suture and floor of maxillary sinus. Thus, it offers the benefit of allowing a two-layered bone fixation and primary stability that is crucial for securing an orthodontic anchorage screw. From a clinical perspective, it manifests as a protuberance following the curve between the alveolar and zygomatic processes of the maxilla.[2]

### Anatomy of Buccal Shelf Area

Mandibular Buccal shelf screw (MBSs), are orthodontic implants placed along the buccal shelf region of the mandible. MBS is bilaterally placed, anterior to the oblique line of the ramus and buccal to the roots of the first and second lower molars. It is covered by the thickest cortical bone in the jaw.[2]

### Discussion

To treat any orthodontic case, it is essential to see the case from every aspect and make all the possible treatment plans. One of the most important modalities of treatment plan is anchorage. Anchorage loss is a reciprocal response that may impede the effectiveness of orthodontic treatment. If the anchorage unit in the force system is embedded within the bone, the reactive forces that consistently arise will theoretically prevent any undesired tooth displacement. This is considered as absolute anchorage which is often necessary in the treatment of cases requiring maximum anchorage.[3]Kitachi[4] stated that implants can be used as absolute anchorage as implants are placed within the bone and do not possess a periodontal ligament. Kanomi[1]coined the term mini-implant. He used 1.2mm X 6 mm mini bone screws. According to Kuroda et al[5] one of the main risk factors for screw failure is its close vicinity to the root.

Hence, taking into consideration both surgical and bio-mechanical perspectives, E-A TADS were introduced by Dr. Eric Liou[6] in 2004 from Taiwan. He developed a method for IZC screw placement adjacent to buccal surface of the maxillary first molar which has provided a promising solution to surpass the constraints of TADS. To achieve best results from the application of these screws, it is utmost important to analyse anatomical considerations of these orthodontic bone screws for safe insertion at proper angulation and bone depth. The stability of E-A bone screws is influenced by anatomical parameters such as bone qualities (including bone density, bone depth, and cortical bone thickness), soft tissue features (differentiating between mucosa and attached gingiva), and the close proximity to certain anatomical elements (such as roots, nerves, arteries, and sinus/nasal canals).

### Anatomical Considerations of Infra Zygomatic Screws

**1. Size of Bone Screw**

These are at least 2 mm in diameter and 8–14 mm in length, making them comparatively larger than inter radicular implants. Chen et al[7] found in their research that micro implants with a length of 2mm X 8mm are effective for orthodontic anchorage. In addition, Lin and Robert[8] have established the same results noting that the ends of 12mm screws could touch the roots of the molars, which could hinder the en-mass distalization of maxillary arch.

**2. Site of Insertion and Angulation**

To properly evaluate the site of insertion CBCT of the patient needs to be done. Bone thickness is measured at different angles with respect to occlusal plane. Along with this root clearance and sinus proximity are also considered during evaluation of site of placement.

Lin, suggested positioning bone screws in between 1st and 2nd molars, while Liou, proposed the placement of screw more anteriorly at the mesiobuccal aspect, adjacent to the roots of the 1st molar.[9] He reported that the ideal site for inserting IZCs in an adult infra zygomatic crest is 14–16 mm above the maxillary occlusal plane at an angle of 55° to 70° according to clinical implications.[10] Lima et al[11] demonstrated that the ideal location to put an IZC miniscrew is 11 mm above the alve-olar crest, between upper first and second molars butNazir[12] in his studies considered 7 to 9 mm distance as safest from the alveolar crest if miniscrew is placed along the mesial root of the upper second molar at an angle of 55°–75°with respect to occlusal plane of the upper first molar. This is to make sure that the miniscrew is stable and doesn't damage any nearby structures.

**3. Bone Quality**

The clinical immobility of OBS depend upon primary stability which directly depends on the thickness of the existing cortical bone. According to Fransworth[13], the typical infra-zygomatic bone width is just 1.44 to 1.58 mm. Mavropoulos et al[14] has stated that appropriate cortical bone thickness required for the stability of the implantsis 1-2 mm. Liou et al[10] measured bone depth at different angulations which was 5.2 mm at 40° insertion angle and 8.8 mm at 75° insertion angle but Chen et al[15]took 5.8 mm as the average depth. According to Baumgaertel and Hans,[16]maximum bone depth was found at 11.48 mm if distance is measured apical to cementoenamel junction (CEJ) of the molar whereas with research Nazir[12] in his latest report stated that it is safe to insert the IZCs at a distance of 7 mm to 9 mm above the alveolar crest as this region consists of appropriate bone thickness of 4.5mm required for the stability of miniscrew. Murugesan et al[17] and Amri et al[18] recommended use of 9 to 11 mm implants if inserted 12 to 17 mm apical to the occlusal plane at 65° to 70° angulation.

**4. Maxillary Sinus Penetration**

According to Jia and Chen,[19] IZC penetration through the cortical bony plates and a penetration depth restriction of no more than 1 mm in to the maxillary sinusis advised. Chang et al[20] stated that bone density at the IZC site is increased with the agethat counteracts the loss of bone quantity at the interface, meaning that sinus penetration had no significant effect on the survival rate of IZC. Further research is required because the literature on the negative effects of perforation is debatable.

## Anatomical Considerations of Mandibular Buccal Shelf Screws

**1. Size of Bone Screw**

Most commonly screw dimension for mandibular buccal shelf area used is 2 mm X 12 mm. Michał Sarul et al[21] suggest that 10 mm long and 1.8–2.0 mm diameter miniscrews are the preferred choice for anchorage in the mandibular buccal shelf, despite causing more frequent inflammation and prolonged pain compared to smaller screws. The mesial side of the second molar is deemed a safe site for MBS orthodontic anchoring screws due to its flatter slope and greater distance from the molar root.

**2. Site of Insertion**

Due to an increase in bone thickness in the MBS posteriorly, Vargas et al[22] and Correa et al[23] confirmed that the buccal region of the second molar distal root is the ideal location for miniscrew installation in the MBS. As the distance from alveolar crest and angulation of BSs insertion, it results in more cortical bone thickness as it moves distally from the first molar to the second molar.

**3. Angulation of Placement**

Chang et al[24] and Sivakumar A et al[17] proposed that BS screw achieve its primary stability when inserted at an angle of 30° lateral to first and second lower molars. Distal to the mandibular second molar was recommended location for buccal shelf implant placement, according to Athira V. M. et al[25]The buccal shelf implant positioned at 30°angulation to the tooth's long axis and at a linear distance of 7mm from the alveolar crest revealed the greatest amount of cortical bone, distal to the second molar.

**4. Bone Quality**

The minimum base value for the buccal extension of the MBS is considered to be 5 mm of buccal bone thickness for safe mini-screw insertion in which 1.7 mm is for root safety distance, screw thickness is 1.6 mm, and the cortical buccal bone safety distance is 1.7 mm.Chang at el[24] suggested that interproximal area to be the best site where we can get adequate bone thickness of 3.54mm-4.05mm if placed 5-7mm below alveolar crest. Nuceraa et al[26] proposed that the optimal anatomic characteristics is the mandibular buccal bone is found at a depth of 19.91mm corresponding to the distal root of second molar, with screw insertion buccal to the cementoenamel junction at distance of 4mm. Patni and potnis[27] proposed that in Indian patients, 8 mm from the CEJ is optimal distance with total bone width of (6.40 ± 1.35) mm.

Sreenivasagan and Sivakumar[28] observed maximum total bone thickness is foundon the distobuccal aspect of 2nd molar at a depth of 8 mm i.e. (6.41±0.29 mm) as well as maximum root clearance of 5.35mm.

**5. Proximity To Inferior Alveolar Nerve**

Inferior alveolar nerve is situated in the mandible's body is at its most significant the buccal area at the distal root of the second molar. Therefore, the inferior alveolar nerve is most susceptible to iatrogenic damage when bone screws are inserted in close proximity to the mandibular second molar and towards its distobuccal aspect. According to Mathews,[29] cortical bone thickness and root clearance both increase with insertion depth provided that there is sufficient soft tissue clearance (roughly 5 mm), screws can be placed in either attached or movable mucosa. According to Changa et al,[30] placement in MM or AG did not significantly differ from one another.

## Conclusion

The advent of extra alveolar bone screws, it has provided an ease to the clinicians to correct underlying mild skeletal problems with non-surgical treatment modalities. Therefore, based on the data from the literature, it can be concluded that for optimal stability and fracture resistance, high density and high-quality bone is required which is found at infra zygomatic crest area in maxilla and buccal shelf region in mandible.

The specifications for Intra-Zygomatic Crest (IZC) and mandibular buccal shelf Screw (MBS) procedures outline key details for screw design, placement, and considerations for both techniques. IZCs should be 10 mm long by 2 mm diameter stainless steel screw should be placed 2 mm apical to the mucogingival junction at the roots of the zygomatic crest eminence on the buccal aspect of the alveolar mucosa. The insertion angle should range from 55-75 degrees for adequate root clearance. Optimal bone quality with 5mm of bone depth and 2mm of bone width lies interdentally between the first and second maxillary molars, with a permissible sinus floor perforation of 1mm for bicortical engagement. Movable mucosa or attached gingiva doesn't significantly affect screw stability. Conversely, for MBS, a 12mm stainless-steel screw with a diameter of 2.0mm is suggested, placed 4mm buccal and 5mm-8mm below the cementoenamel junction on the distal aspect of second molar. The screw should be inserted along the long axis of root or angled at 30°, with at least 1.5mm clearance between the screw and the root. Adequate bone thickness and depth are crucial, with caution taken to avoid the inferior alveolar nerve. Similar to IZCs, the stability of MBS isn't significantly impacted by the type of gingiva.

Even though we have explored factors such as screw design, site of placement, insertion angle, bone quality, proximity to adjacent structures in enough depth but there are other determinants also such as insertion technique, patient's oral hygiene, amount of force being applied which needs to be further evaluated to check the stability of orthodontic bone screw.

**Refrences**


1. Kanomi R. Mini-implant for orthodontic anchorage. J clin Orthod. 1997;31:763-7.
2. Ghosh A. Infra-zygomatic crest and buccal shelf-Ortho-dontic bone screws: A leap ahead of micro-implants Clinical perspectives. J Indian Orthod Soc. 2018; 52 (4): 127-41.
3. Lam R, Goonewardene MS, Allan BP, Sugawara J. Success rates of a skeletal anchorage system in orthodontics: A retrospective analysis. Angle Orthod. 2018; 88 (1): 27-34.
4. Rungcharassaeng K, Caruso JM. Implants as absolute anchorage. J Calif Dent Assoc. 2005; 33 (11): 881-8.
5. Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Yamamoto TT. Root proximity is a major factor for screw failure in orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2007;131(4):68-73.
6. Liou EJ, Pai BC, Lin JC. Do miniscrews remain stationary under orthodontic forces? Am J Orthod Dentofacial Orthop. 2004;126 (1): 42-7.
7. Tseng YC, Hsieh CH, Chen CH, Shen YS, Huang IY, Chen CM. The application of mini-implants for orthodontic ancho-rage. Int J Oral Maxillofac Surg. 2006; 35 (8): 704-7.
8. Lin J, Roberts E. CBCT imaging to diagnose and correct the failure of maxillary arch retraction with IZC screw ancho-rage. Int j orthodimplantol. 2014; 35 (3): 4-17.
9. Pathak S, Patil T, Mahamuni A, Jaju K, Rai R. Mandibular buccal shelf and infra zygomatic crest–A safe zone for mini screw insertion. Indian J Orthod Dentofacial Res. 2019; 5 (2): 60-2.
10. Liou EJ, Chen PH, Wang YC, Lin JC. A computed tomo-graphic image study on the thickness of the infrazygomatic crest of the maxilla and its clinical implications for miniscrew insertion. Am J Orthod Dentofacial Orthop. 2007; 131(3): 352-6.
11. Lima Jr A, Domingos RG, Ribeiro AN, Neto JR, de Paiva JB. Safe sites for orthodontic miniscrew insertion in the infra-zygomatic crest area in different facial types: A tomo-graphic study. Am J Orthod Dentofacial Orthop. 2022; 161 (1): 37-45.
12. Nazir SZ. Quantitative Measurement of Buccal Cortical Bone Thickness in Infrazygomatic Crest Area at Different Alveolar Bone Heights and Insertion Angles of Infra-zygomatic Crest Screws: A CBCT Study. J Indian Orthod Soc. 2024; 33 (5): 78-85
13. David Farnsworth P, Rossouw E, Ceen RF, Buschang PH. Cortical bone thickness at common miniscrew implant placement sites. Am J Orthod Dentofacial Orthop 2011; 13 (9): 495- 503.
14. Mavropoulos A, Kiliaridis S, Bresin A, Ammann P. Effect of different masticatory functional and mechanical demands on the structural adaptation of the mandibular alveolar bone in young growing rats. Bone. 2004; 35 (6):191-9.
15. Y-J Chen, C-T Kao, T-H. Huang Evaluation of ten extra-alveolar temporary anchorage device insertion sites by cone beam volumetric computer tomography: A pilot study. J Dent Sci. 2010; 5 (1): 21-9.
16. Baumgaertel S, Hans MG. Assessment of infrazygomatic bone depth for mini-screw insertion. Clin Oral Implants Res. 2009; 20 (6): 638-42.
17. Murugesan A, Sivakumar A. Comparison of bone thickness in infrazygomatic crest area at various miniscrew insertion angles in Dravidian population a cone beam computed tomography study. Int Orthod. 2020;18 (1):105-14.
18. Al Amri MS, Sabban HM, Alsaggaf DH, Alsulaimani FF, Al-Turki GA, Al-Zahrani MS et al. Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal. Ann Saudi Med. 2020; 40 (4): 330-7.
19. Jia X, Chen X, Huang X. Influence of orthodontic mini-implant penetration of the maxillary sinus in the infra-zygomatic crest region. Am J Orthod Dentofacial Orthop. 2018; 153 (5): 656-61.
20. Chang CH, Lin JH, Roberts WE. Success of infrazygomatic crest bone screws: patient age, insertion angle, sinus penetration, and terminal insertion torque. Am J Orthod Dentofacial Orthop. 2022;161(6):783-90.
21. Sarul M, Lis J, Park HS, Rumin K. Evidence-based selection of orthodontic miniscrews, increasing their success rate in the mandibular buccal shelf. A randomized, prospective clinical trial. BMC Oral Health. 2022; 22 (1): 41-4.
22. Vargas EO, de Lima RL, Nojima LI. Mandibular buccal shelf and infrazygomatic crest thicknesses in patients with different vertical facial heights Am J Orthod Dentofacial Orthop. 2020;158 (3): 349- 56.
23. Escobar-Correa N, Ramírez-Bustamante MA, Sánchez-Uribe LA, Upegui-Zea JC, Vergara-Villarreal P, Ramírez-Ossa DM. Evaluation of mandibular buccal shelf characteristics in the Colombian population: A cone beam computed tomography study. Korean J Orthod. 2021; 51 (1): 23
24. Chang C, Huang C, Roberts WE. 3D cortical bone anatomy of the mandibular buccal shelf: a CBCT study to define sites for extra-alveolar bone screws to treat Class III mal-occlusion. Int J OrthodImplantol. 2016; 41(1): 74-82.
25. Athira VM, Shashidhar K, Kuttappa MN, Nayak UK, Ravi MS, D'Souza N. Safe sites for buccal shelf bone screw placement in various skeletal malocclusions: A CBCT study. J Orthod. Sci. 2023;12 (1): 63.
26. Nucera R, Lo Giudice A, Bellocchio AM, Spinuzza P, Cap-rioglio A, Perillo L et al. Bone and cortical bone thickness of mandibular buccal shelf for mini-screw insertion in adults. Angle Orthod. 2017; 87 (5): 745-51.
27. Kolge NE, Patni VJ, Potnis SS. Tomographic mapping of buccal shelf area for optimum placement of bone screws: a three dimensional cone beam computed tomography evaluation. APOS Trends Orthod. 2019; 9 (4): 241-5.
28. Sreenivasagan S, Sivakumar A. CBCT comparison of buccal shelf bone thickness in adult Dravidian population at various sites, depths and angulation A retrospective study. Int Orthod. 2021;19 (3): 471-9
29. Mathews MC, Bejoy PU. Virtual Placement of The Mandi-bular Buccal Shelf Bone Screw: A CBCT Evaluation. J ContempOrthod. 2021; 5 (2): 42-8.
30. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf mini-screws placed in movable mucosa or attached gingiva. Angle Orthod. 2015; 85 (6): 905-10.

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# Clinical Evaluation of Aesthetic Rehabilitation of Anterior Teeth Using Componeers, Porcelain Veneers, and Zirconia Veneers – An In Vivo Study (Based on USPHS Criteria)

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## Abstract

**Background:** The aesthetic rehabilitation of anterior teeth is a cornerstone of modern dentistry, with increasing patient demand for minimally invasive, natural looking solutions. Various veneer systems, including prefabricated composite laminate veneers (Componeers), porcelain veneers, and zirconia veneers, offer different advantages. However, their long-term clinical performance needs comparative evaluation.

**Aim:** This study aimed to evaluate and compare the clinical performance of Componeers, porcelain veneers, and zirconia veneers in the aesthetic rehabilitation of anterior teeth using United States Public Health Service (USPHS) criteria.

**Materials and Methods:** A total of 45 patients (aged 18–40 years) requiring anterior aesthetic rehabilitation were enrolled and divided into three groups (n=15 each): Group A (Componeers), Group B (porcelain veneers), and Group C (zirconia veneers). Veneers were placed following standardized adhesive protocols. Patients were recalled at 6, 12, and 24 months for evaluation using modified USPHS criteria (color match, marginal adaptation, surface texture, marginal discoloration, retention, and secondary caries). Statistical analysis was performed using Chi-square and ANOVA tests, with significance set at $p<0.05$.

**Results:** At 24 months, zirconia and porcelain veneers demonstrated superior performance compared to Componeers in terms of color stability ($p<0.05$). Marginal adaptation and surface texture were significantly better in porcelain and zirconia veneers. Componeers exhibited higher incidence of marginal discoloration (20%) and minor surface roughness. No cases of debonding or secondary caries were reported in zirconia veneers, while one debonding occurred in each of the other two groups.

**Conclusion:** Zirconia and porcelain veneers demonstrated excellent clinical outcomes over a 2-year period, while Componeers provided satisfactory short-term aesthetics with the advantage of reduced chair time. Choice of material should balance patient expectations, cost, and long-term prognosis.

**Keywords:** Componeers, porcelain veneers, zirconia veneers, aesthetic rehabilitation, anterior teeth, USPHS criteria

## Introduction

The demand for aesthetic dentistry has surged with patients seeking minimally invasive and natural looking restorations for anterior teeth. Veneers, both direct and indirect, play a significant role in addressing discolorations, malformations, fractures, and diastema closure while preserving tooth structure.

Componeers are prefabricated composite laminate veneers introduced as an economical and chairside alternative to porcelain veneers. While they provide immediate aesthetic improvement, concerns exist regarding their long-term performance, particularly in terms of color stability and surface integrity. Porcelain veneers, widely regarded as the gold standard, offer excellent aesthetics and biocompatibility but are technique sensitive and relatively expensive. Zirconia veneers, a more recent development, combine high strength with improved translucency, making them suitable for both functional and aesthetic demands.

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Few clinical studies have comprehensively compared these three systems under standardized conditions. Hence, this study aimed to evaluate the clinical performance of Componeers, porcelain veneers, and zirconia veneers using USPHS criteria in an in vivo setting.

**Figure 1.Preoperative condition showing discoloration and mild malformation of maxillary anterior teeth.**

## Materials and Methods

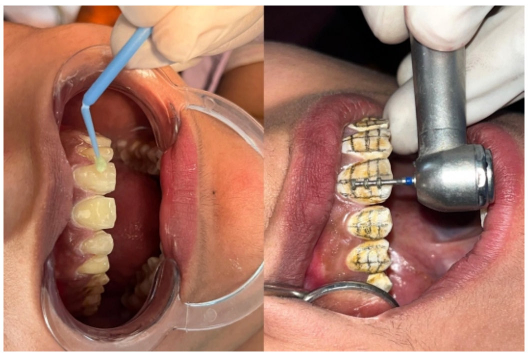

**Figure2 :Clinical steps of veneer placement**

**Study design:** Prospective, randomized, in vivo comparative clinical study.

**Sample Size and Selection:** Forty-five patients aged 18–40 years with unaesthetic anterior teeth due to discoloration, mild malformation, or diastema were selected from the Department of Conservative Dentistry and Endodontics. Patients with parafunctional habits, poor oral hygiene, extensive caries, or periodontal disease were excluded. Ethical clearance and informed consent were obtained.

**Grouping:** Patients were randomly allocated into three groups:

- Group A (n=15):Componeers (IvoclarVivadent)
- Group B (n=15): Porcelain veneers
- Group C (n=15): Zirconia veneers

## Clinical Procedure

- Tooth preparation was performed using minimally invasive techniques (0.3–0.7 mm reduction).
- For Componeers, prefabricated veneers were selected, etched, bonded with universal adhesive, and luted with composite resin.
- For porcelain and zirconia veneers, digital impressions were taken, veneers were fabricated using CAD/CAM, and bonded with dual cure resin cement following standard adhesive protocols.

**Evaluation:** Patients were recalled at 6, 12, and 24 months. Clinical evaluation was performed by two blinded examiners using modified USPHS criteria:

- Color Match
- Marginal Adaptation
- Surface Texture
- Marginal Discoloration
- Retention
- Secondary Caries

**Statistical Analysis:** Data were analyzed using SPSS v25. Chi-square and ANOVA tests were applied. $p<0.05$ was considered statistically significant.

| Group | Material | N (Patients) | Adhesive Protocol | Luting Cement | Fabrication | Recall Intervals (Months) |
|---|---|---|---|---|---|---|
| A | Componeers (prefabricated composite laminate veneers) | 15 | Etching, universal adhesive application | Light-cure composite resin | Prefabricated | 6, 12, 24 |
| B | Porcelain veneers | 15 | Etching, silanization, adhesive bonding | Dual-cure resin cement | CAD/CAM | 6, 12, 24 |
| C | Zirconia veneers | 15 | Air-abrading, primer, adhesive bonding | Dual-cure resin cement | CAD/CAM | 6, 12, 24 |

**Table 1. Group allocation and clinical procedure details for each veneer system.**

## Results

At 6 months, all three groups showed excellent results with no significant differences. However, at 12 and 24 months, differences emerged:

- **Color match:** Zirconia (100%) and porcelain veneers (93.3%) maintained superior color stability compared to Componeers (73.3%).
- **Marginal Adaptation:** Porcelain (93.3%) and zirconia (100%) outperformed Componeers (80%).
- **Surface Texture:** Zirconia showed the smoothest surfaces with no deterioration, while Componeers exhibited minor roughness (20%).
- **Marginal Discoloration:** Highest in Componeers (20%) compared to porcelain (6.6%) and zirconia (0%).
- **Retention:** Only one case of debonding was observed in Componeers and porcelain veneers each, while zirconia veneers showed 100% retention.
- **Secondary Caries:** None observed in any group.

Overall, zirconia veneers showed the best performance, followed by porcelain veneers, while Componeers, though clinically acceptable, exhibited higher rates of minor failures.

| Parameter | Group A (Componeers) | Group B (Porcelain) | Group C (Zirconia) | p-Value |
|---|---|---|---|---|
| Color match (Alfa %) | 73.3% | 93.3% | 100% | <0.05* |
| Marginal adaptation (Alfa %) | 80% | 93.3% | 100% | <0.05* |
| Surface texture (Alfa %) | 80% | 93.3% | 100% | <0.05* |
| Marginal discoloration (Bravo/Charlie %) | 20% | 6.6% | 0% | <0.05* |
| Retention (Debonding cases) | 1 | 1 | 0 | NS |
| Secondary caries (cases) | 0 | 0 | 0 | NS |

***Statistically significant difference (Chi-square test, ANOVA); NS = not significant.**

**Table 2.Comparative Evaluation of USPHS Criteria at 24 Months.**

## Discussion

The present study compared Componeers, porcelain veneers, and zirconia veneers using USPHS criteria over a 24-month period. The results demonstrated that while all materials provided acceptable outcomes, zirconia and porcelain veneers were superior in terms of aesthetics and durability.

Componeers offered an immediate, cost effective solution but showed higher susceptibility to marginal discoloration and surface roughness, likely due to the inherent limitations of composite resin materials such as water sorption and wear. These findings align with previous reports that composite veneers may require more frequent polishing and maintenance [1,2].

Porcelain veneers demonstrated excellent aesthetics and marginal adaptation, corroborating earlier long-term studies reporting survival rates exceeding 90% after 10 years [3–6]. The single debonding case may be attributed to adhesive failure or patient related factors.

Zirconia veneers exhibited the highest overall success, with superior strength, biocompatibility, and color stability. Recent advancements in high translucency zirconia have overcome earlier limitations of opacity, making it comparable to lithium disilicate in aesthetics [7–10]. The complete absence of secondary caries or debonding highlights zirconia as a highly reliable option.

The study was limited by its short follow-up period (24 months) and relatively small sample size. Longer-term clinical trials with larger populations are necessary to validate these findings.

**Figure 3.Comparative postoperative appearance of the three veneer systems after 24 months.**

## Conclusion

Within the limitations of this in vivo study:

1. All three veneer systems showed clinically acceptable results based on USPHS criteria at 24 months.
2. Zirconia veneers demonstrated the best performance in terms of aesthetics, retention, and marginal integrity.
3. Porcelain veneers showed comparable results, making them a gold standard for predictable long-term aesthetics.
4. Componeers provided satisfactory outcomes in the short term, making them a suitable choice for patients seeking cost-effective, minimally invasive rehabilitation, but their long-term performance remains inferior.

Clinical decision making should consider patient specific factors such as cost, time, and aesthetic expectations when choosing between these veneer systems.

## References (Vancouver Style)


1. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent. 2000; 28 (3): 163-77.
2. Meijering AC, Creugers NH, Roeters FJ, Mulder J. Survival of three types of veneer restorations in a clinical trial: a 2.5-year follow-up. J Dent. 1998; 26 (7): 563-8.
3. Dumfahrt H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part II--Clinical results. Int J Prosthodont. 1999;12 (6): 483-9.
4. Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation- a retrospective study. Int J Periodontics Restorative Dent. 2005; 25 (1): 9-17.
5. Layton D, Walton TR. An up to 16-year prospective study of porcelain laminate veneers. Int J Prosthodont. 2007; 20 (4): 389-96.
6. Guess PC, Stappert CF, Strub JR. Clinical performance of ceramic veneers: clinical evidence and future perspectives. J Oral Rehabil. 2006; 33 (11): 841-52.
7. Sailer I, Fehér A, Filser F, Gauckler LJ, Lüthy H, Hämmerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont. 2007; 20 (4): 383-8.
8. Zarone F, Russo S, Sorrentino R. From porcelain-fused-to-metal to zirconia: clinical and experimental considerations. Dent Mater. 2011; 27 (1): 83-96.
9. Tinschert J, Schulze KA, Natt G, Latzke P, Heussen N, Spiekermann H. Clinical behavior of zirconia based fixed partial dentures made of DC-Zirkon: 3-year results. Int J Prosthodont. 2008; 21(3): 217-22.
10. Pjetursson BE, Sailer I, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Clin Oral Implants Res. 2007;18Suppl 3: 73-85.

11. Gresnigt MM, Kalk W, Ozcan M. Clinical longevity of ceramic laminate veneers bonded to teeth with and without existing composite restorations up to 40 months. Clin Oral Investig. 2012;16 (2): 659-67.
12. Burke FJ. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. J EsthetRestor Dent. 2012; 24 (4): 257-65.
13. Blatz MB, Sadan A, Kern M. Resin ceramic bonding: a review of the literature. J Prosthet Dent. 2003; 89 (3): 268-74.
14. Beier US, Kapferer I, Burtscher D, Dumfahrt H. Clinical performance of porcelain laminate veneers for up to 20 years. Int J Prosthodont. 2012; 25 (1): 79-85.
15. Chen JH, Shi CX, Wang M, Zhao SJ, Wang H. Clinical evaluation of 546 tetracycline stained teeth treated with porcelain laminate veneers. J Dent. 2005; 33 (1): 3-8.

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# Prevalence, Morphology and Location of Maxillary Sinus Septa using Cone Beam Computed Tomography (CBCT): A Review with Emphasis on North Indian Populations

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## Abstract

**Background:** Maxillary sinus septa (Underwood's septa) are common anatomical variations that may complicate sinus augmentation and posterior maxillary implant placement. Cone-beam computed tomography (CBCT) allows precise three dimensional evaluation of septa morphology, number, orientation, height, and location.

**Objective:** This review aimed to summarize CBCT based literature on the prevalence, morphology, and typical locations of maxillary sinus septa, with emphasis on North Indian populations, and to discuss the clinical implications and limitations of CBCT for surgical planning.

**Methods:** A systematic search of PubMed/PMC, Scopus, and Google Scholar was conducted for studies up to 2025 using keywords related to maxillary sinus septa and CBCT. Human CBCT or CT studies with ≥5 patients and quantitative data on septa prevalence or morphology were included. Extracted data included prevalence, septa number, orientation, height, location, dentition correlation, and CBCT parameters.

**Results:** The global pooled prevalence of maxillary sinus septa is approximately 41% per patient, though individual studies report 25–56% depending on population and methodology. North Indian CBCT studies report lower prevalence (8.9–21.3%) but similar morphology predominantly single, bucco-palatal orientation, middle region (first molar area) predominance, and mean height 4–8 mm. Presence of septa increases the risk of Schneiderian membrane perforation during lateral window sinus augmentation. CBCT limitations include voxel size, field of view (FOV), and inter-observer variability.

**Conclusions:** CBCT is the imaging modality of choice for preoperative evaluation of maxillary sinus septa. Standardized reporting and awareness of CBCT limitations improve surgical safety and inter-study comparability. Population specific data, particularly from North India, highlight variability that should guide clinical planning.

## Introduction

The maxillary sinus exhibits several anatomical variations, among which bony septa (Underwood's septa) are particularly significant. First described by Underwood in 1910, these bony projections within the sinus cavity can complicate sinus floor elevation and implant placement due to an increased risk of Schneiderian membrane perforation.[1,5,10] The reported prevalence of septa ranges between 25% and 56%, depending on population characteristics, imaging methodology, and diagnostic criteria.[1,3,4] Typically, septa appear as single bony partitions, most often bucco-palatal in orientation and located in the middle region corresponding to the first molar area.[5,11]

Advancements in imaging technology, particularly the introduction of CBCT, have enabled precise evaluation of the maxillary sinus in three dimensions (Fig. 1), providing detailed information about the presence, number, height, and orientation of septa. Compared with conventional radiography, CBCT offers superior spatial resolution, lower radiation dose relative to CT, and accurate visualization of fine anatomical structures.[2,3,13] Consequently, CBCT has become the preferred imaging modality for sinus evaluation and implant planning.

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Despite numerous global studies, data from North Indian populations remain limited.[8] Considering regional anatomical variability, such data are essential for optimizing implant planning and minimizing intraoperative complications.[2,7] Hence, this review integrates global CBCT based findings with a particular focus on the North Indian population.

## Rationale and Objectives

This review aims to:

1. Summarize global CBCT derived estimates of the prevalence, morphology, and location of maxillary sinus septa.[1,3,4]
2. Highlight CBCT based findings specific to North Indian populations to provide population-specific clinical guidance.[2,7]
3. Discuss clinical implications, limitations of CBCT assessment, and propose a standardized reporting approach for sinus septa.[6,13]

## Methods

### Search Strategy

A systematic search of PubMed/PMC, Scopus, and Google Scholar was conducted up to January 2025 using the following keywords: maxillary sinus septa, Underwood septa, cone-beam computed tomography, CBCT, prevalence, morphology, India, North India, sinus lift.

### Inclusion Criteria

- Human CBCT or CT studies evaluating sinus septa.[1–3,7]
- Sample size ≥ 5 patients.
- Quantitative data on prevalence, orientation, height, or location.

### Exclusion Criteria

- Case reports (<5 patients), cadaver only studies, or those lacking imaging methods.
- Reviews without original CBCT data.

### Data Extraction

For each study, the following were recorded: author, year, country/region, sample size, CBCT machine, voxel size, field of view (FOV), slice thickness, septa prevalence per patient/sinus, number, orientation, height, location, dentition correlation, and risk of Schneiderian membrane perforation.[6,10]

### Quality Assessment

Studies were evaluated using a modified Newcastle Ottawa scale for observational imaging research, emphasizing observer calibration, CBCT resolution, and septa definition criteria.[13]

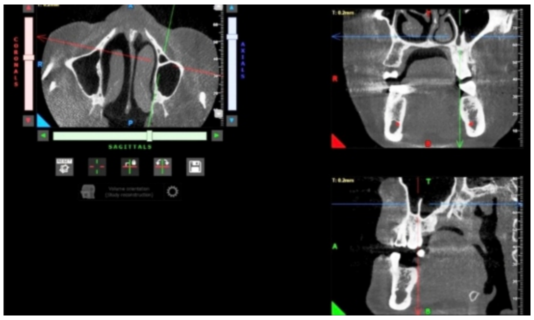

Figure 1: View of septa in CBCT sections

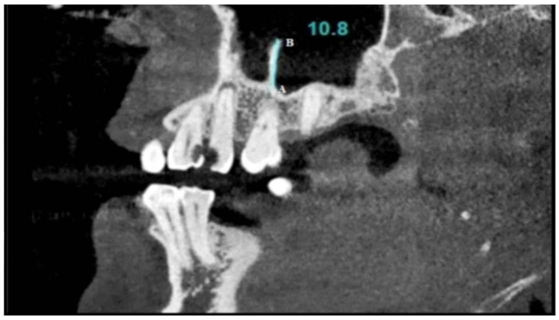


Figure 2: Length of the sinus septa in coronal plane

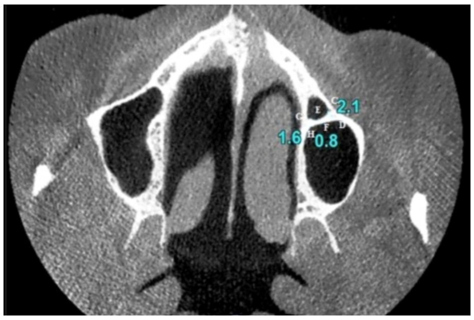


Figure 3: Width of horizontal sinus septa in axial view

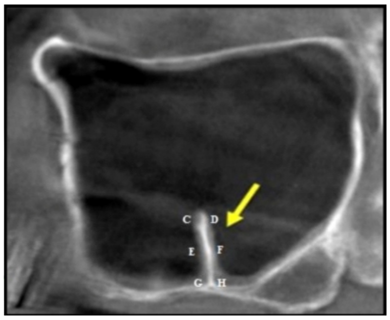


Figure 4: Width of vertical sinus septa in coronal view

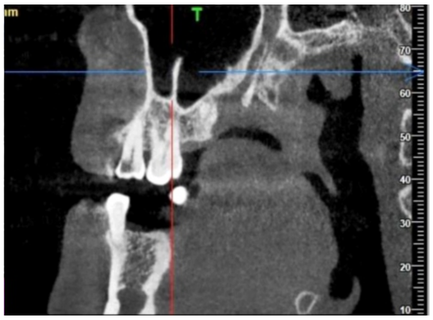


Figure 5: CBCT image of posterior sinus septa

## Results

Global pooled prevalence and variability: A 2022 systematic review and meta-analysis of CT and CBCT studies pooled 9,631 patients and reported a pooled prevalence of ~41% per patient (95% CI 36–46%), but noted high heterogeneity ($I^2$ high). Differences were attributed to imaging modalities, septa definitions, and population differences.[1,3] Individual CBCT studies report prevalence ranges typically between ~25% and 56%, reflecting differences in cohort selection, measurement thresholds, and methodology.[3,4,13]

**Morphology:** number, orientation, and height: When present, septa are more often single than multiple, with many studies reporting ~85–90% single septa among sinuses with septa. The bucco-palatal orientation, i.e., vertical plate between buccal and palatal walls, is most common (Fig. 3), while antero-posterior orientations are less frequent. Reported mean septa height commonly falls in the ~4–8 mm range[9] (Fig. 2). Notably, many studies define "clinically significant" septa as those ≥2–4 mm in height; for example, Verma et al. (2024) reported a mean septa height of ~6.16 mm.[2]

**Location (Anterior/Middle/Posterior):** Septa are variably located in anterior, middle, or posterior thirds of the sinus (Fig.4). Underwood's original description correlated septa with regions between tooth roots. Several modern CBCT studies report the middle region (first molar area) as most common, although some populations demonstrate anterior or posterior predominance, reflecting inter-study variability.[5,11]

**North Indian population data:** Verma (2024) reported a prevalence of 21.3%, with most septa single (≈90.6%), located in the middle region (≈48.4%), predominantly bucco-palatal (≈93.8%), and mean height ~6.16 mm.[2] A large Northeast Indian cohort (Verma et al., 2025) of 1,160 subjects demonstrated a prevalence of 8.88%, highlighting substantial regional variation and the need for population-specific data.[12]

**Clinical Impact:** The presence of septa, especially complete septa crossing the lateral window area, is associated with a higher risk of Schneiderian membrane perforation during lateral window sinus augmentation (Fig. 5). Preoperative CBCT identification allows modification of surgical technique to reduce intraoperative complications.[6]

## Discussion

**Main findings:** CBCT studies and meta-analytic data confirm that maxillary sinus septa are common anatomical variations with pooled prevalence around 40% per patient. North Indian CBCT series report lower prevalence in some cohorts (8.9–21.3%) compared with global estimates. Morphology when present remains consistent: single septa, bucco-palatal orientation, middle region predominance, and heights commonly 4–8 mm.[1–5,11] The presence of septa increases the risk of Schneiderian membrane perforation, emphasizing the importance of preoperative CBCT assessment.[2,7,13]

**Why Prevalence Varies:** Reported variability arises from methodological differences, including thresholds for what qualifies as a septum (e.g., minimum height for clinical significance, typically ≥2–4 mm), observer calibration, CBCT voxel size and field of view, and whether prevalence is reported per patient or per sinus. Population factors such as dentition status, age, sinus pneumatization, and genetic differences further influence septa prevalence. Reporting bias and study design (single center vs multicenter) also contribute to variation.[2,3,7,13]

**Clinical Implications:** Preoperative CBCT is strongly recommended for candidates of lateral sinus augmentation or posterior maxillary implant placement with anatomic uncertainty. Surgeons should identify septa number, location, orientation, and height, and document relation to the planned lateral window. High or complete septa may require modified lateral window designs (e.g., split windows or septum sectioning) to minimize membrane perforation risk. Explicit reporting of septa in CBCT and surgical planning notes enhances communication and surgical safety.[6]

**Standardized CBCT Reporting Recommendations:** For each sinus, report presence/absence, number of septa, location (anterior/middle/posterior), orientation (bucco-palatal, antero-posterior, or oblique), maximum measured height (mm) with measurement method, relationship to planned surgical site, and suggested surgical considerations.[2,5,13]

**Limitations & future Directions:** Heterogeneity in definitions and measurement techniques limits direct comparability across studies. Regional representation is limited in India, with North Indian prevalence showing variability. Future multicenter CBCT studies should adopt standardized minimum criteria (e.g., minimum septa height, measurement planes), report per-sinus and per-patient prevalence, and incorporate dentition/pneumatization history to differentiate primary vs secondary septa origins.[2,7,13]

## Conclusion

Maxillary sinus septa are clinically significant anatomical variations that can influence sinus lift and implant procedures. CBCT remains the preferred imaging modality for their evaluation, offering accurate three dimensional assessment essential for surgical planning.[2,3,5,6,11,13] Although North Indian studies show a lower prevalence than global averages, septa morphology remains comparable. Emphasizing explicit CBCT reporting and awareness of imaging limitations enhances diagnostic reliability, surgical safety, and cross-population research consistency.[2,7,13]

## References


1. Henriques I, Caramês J, Francisco H, et al. Prevalence of maxillary sinus septa: systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2022; 51 (7): 823-831. doi: 10.1016/j.ijom.2022.02.003
2. Verma R, Dua N, Gupta R, et al. Evaluation of maxillary sinus septa using CBCT: A retrospective study. Cureus. 2024; 16 (8): e68157. doi:10.7759/cureus.68157
3. Abesi F, Motaharinia Y, Ghaffari T, et al. Systematic review and meta-analysis of CBCT studies on maxillary sinus septa. J Clin Exp Dent. 2023;15 (3): e249-e255. doi: 10. 4317/jced.56467
4. Yuksel IB, Erdem A, Akinci A, et al. Radiographic prevalence and anatomical characteristics of maxillary sinus septae: CBCT study. BMC Oral Health. 2025;25(1):45. doi:10.1186/s12903-025-06268-9
5. Bornstein MM, Seiffert M, Maestre-Ferrín L, et al. Analysis of frequency, morphology, and locations of maxillary sinus

septa using CBCT. Int J Oral Maxillofac Implants. 2016; 31 (2): 280–287. doi:10.11607/jomi.4200
6. Al-Dajani M. Incidence, risk factors, and complications of Schneiderian membrane perforation in sinus lift surgery: A meta-analysis. Implant Dent. 2016;25(3):409–415. doi: 10.1097/IDS.0000000000000293
7. Paknahad M, Kharazifard MJ, Alavi S, et al. Prevalence and features of maxillary sinus septa in patients with cleft lip and palate compared to non-CLP individuals: CBCT study. J Craniofac Surg. 2024;35(5):e463-e467. doi: 10.1097/SCS.0000000000007105
8. Mudgade D, Motghare P, Kunjir G, et al. Prevalence of anatomical variations in maxillary sinus using CBCT. J Indian Acad Oral Med Radiol. 2018; 30 (1):18–23. doi: 10.4103/jiaomr.jiaomr_51_17
9. Laçin N, Izol BS. Evaluation of septa in maxillary sinus with CBCT. Int Dent Res. 2019; 9 (2): 41–45
10. Naitoh M, Suenaga Y, Kondo S, et al. Assessment of maxillary sinus septa using CBCT: Etiological consideration. Clin Implant Dent Relat Res. 2009;11(s1): e52–e58. doi: 10.1111/j.1708-8208.2009.00199.x
11. Takeda D, Hasegawa T, Saito I, et al. Radiologic evaluation of incidence and morphology of maxillary sinus septa in Japanese dentate maxillae. Oral Maxillofac Surg. 2019; 23 (2): 233–237. doi:10.1007/ s10006-019-00780-5
12. Verma R, Dua N, Gupta R, Singh A, Sharma P. Assessment of maxillary sinus septa in Northeast Indian population: A retrospective CBCT evaluation. J Pharm Bioallied Sci. 2025;17(Suppl2): S1328-S1330. doi:10.4103/ jpbs.jpbs_1704_24
13. Hungerbühler A, Rostetter C, Lübbers H-T, et al. Anatomical characteristics of maxillary sinus septa visualized by CBCT. Int J Oral Maxillofac Surg. 2019; 48 (3): 382–387. doi: 10. 1016/j.ijom.2018.10.013

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# Morphometric Analysis and Variations of Mandibular Canal: A Retrospective Study

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## Abstract

**Background:** The mandibular canal (MC) is a vital anatomical structure extending from the mandibular foramen to the mental foramen, carrying the inferior alveolar neurovascular bundle. Variations in its morphology, course, and position are common and clinically significant, influencing implant placement, anesthesia, and surgical procedures. Accurate knowledge of these variations is essential to minimize iatrogenic injuries.

**Objective:** This study aims to assess the morphometric characteristics and anatomical variations of the mandibular canal in a North Indian population using cone beam computed tomography (CBCT).

**Methods:** A retrospective analysis was performed on 100 CBCT scans to evaluate the canal's position, diameter, length, horizontal and vertical location, relationship with mandibular roots, length of the anterior loop of the mental nerve, and overall morphology.

**Results:** The study observed significant variations in the mandibular canal's course, diameter, and relationship to adjacent anatomical landmarks. Differences in the canal's morphology and anterior loop length were evident, highlighting the importance of population specific data for accurate preoperative planning.

**Conclusion:** CBCT provides a reliable, three dimensional assessment of mandibular canal anatomy, aiding clinicians in identifying variations and reducing the risk of iatrogenic complications. Understanding these variations enhances surgical safety, improves implant planning, and contributes to better patient outcomes.

## Keywords

Mandibular canal, Cone beam computed tomography, Inferior alveolar nerve, Anatomy, Morphological variations, Oral surgery.

## Introduction

The mandibular canal (MC) is a vital anatomical structure extending bilaterally from the mandibular foramen to the mental foramen, carrying the inferior alveolar nerve, artery, and vein. Its course and morphology have long been subjects of clinical importance due to their significant role in dental procedures, particularly in implantology, anesthesia, and surgical interventions [Ref]. Variations in the MC's anatomy, such as differences in its shape, course, curvature, and terminal segment, are common and often influenced by racial and ethnic factors [Ref]. These variations can complicate preoperative planning and increase the risk of iatrogenic injuries if not properly understood.

Iatrogenic damage to the inferior alveolar nerve (IAN) is among the most concerning complications in oral and maxillofacial procedures, occurring during implant placement, third molar extraction, osteotomies, bone graft harvesting, and local anesthesia administration [Ref]. Such injuries can range from transient paresthesia to permanent anesthesia, significantly affecting patient quality of life. Even indirect compression from nearby implants or hematomas can lead to neuropraxia, resulting in nerve dysfunction without direct contact [Ref]. Therefore, thorough knowledge of the mandibular canal's anatomy and its spatial relationship with surrounding structures is essential to minimize surgical risks and improve treatment outcomes.

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Traditional two dimensional imaging modalities, such as panoramic, periapical, and occlusal radiographs, have been widely used for mandibular assessment. However, these techniques have inherent limitations, including image distortion, magnification errors, superimposition of anatomical structures, and lack of buccolingual information [Ref]. These limitations hinder accurate localization of the mandibular canal, particularly in assessing its proximity to tooth roots, variations in trajectory, and the presence of bifid or trifid canals.

Cone beam computed tomography (CBCT) has revolutionized maxillofacial imaging by providing high resolution, three dimensional visualization of hard tissues with minimal distortion and superimposition [Ref]. Unlike conventional computed tomography (CT), CBCT delivers detailed images at significantly lower radiation doses, making it particularly suitable for dental and maxillofacial applications [Ref]. Its ability to produce multiplanar reconstructions allows clinicians to accurately identify the position, size, and morphology of the mandibular canal, including variations such as the anterior loop of the mental nerve and additional canal branches that may not be visible on conventional radiographs [Ref].

Understanding these anatomical variations is crucial not only for preventing nerve injuries but also for enhancing surgical safety, improving implant placement accuracy, and optimizing local anesthesia techniques. Furthermore, population based differences in mandibular canal anatomy highlight the importance of region specific data to guide clinical decisions and preoperative planning [Ref].

With the growing demand for implant surgeries and increasing reliance on advanced imaging technologies, reassessing mandibular canal anatomy in different populations has become increasingly important. The present study was undertaken to address this need by analyzing the morphometric features and variations of the mandibular canal in a North Indian population using cone beam computed tomography (CBCT). The study focuses on the canal's position, diameter, length, horizontal and vertical location, relationship to mandibular roots, length of the anterior loop of the mental nerve, and overall morphological patterns.

## Aim of the Study

To analyze the morphometric variations and anatomical characteristics of the mandibular canal in a North Indian population using cone beam computed tomography (CBCT) for improved pre-surgical assessment and clinical planning.

## Materials and Methods

### Study Population and Sample Selection

The present study was conducted using cone beam computed tomography (CBCT) scans obtained from the archives of the Department of Oral Medicine and Radiology. A total of 100 CBCT scans of patients were selected for analysis. All scans included in the study were taken for diagnostic and treatment planning purposes unrelated to this research.

The inclusion criteria were as follows:

- High quality CBCT scans with complete visualization of the mandibular canal region.
- Adult patients with fully erupted mandibular dentition.
- Absence of pathological lesions, fractures, or prior surgical interventions in the mandibular region.

**Exclusion criteria included**

- Poor quality CBCT images with artifacts or incomplete canal visualization.
- Patients with congenital or acquired mandibular deformities.
- Evidence of pathology or previous trauma affecting mandibular canal anatomy.

### Imaging Technique and CBCT Parameters

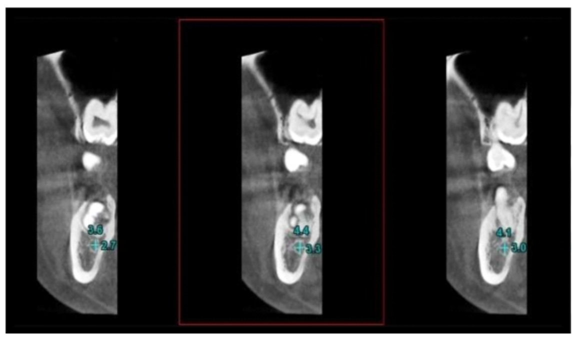
All CBCT scans were acquired using a standard CBCT unit with patients positioned according to the manufacturer's guidelines to ensure reproducibility and accuracy. The scans were obtained with appropriate field of view (FOV) settings, voxel size, and exposure parameters to allow detailed evaluation of mandibular structures. Three dimensional reconstructions were generated using specialized imaging software, and multiplanar reformatted (MPR) views axial, coronal, and sagittal were used for measurements and morphometric analysis.

### Anatomic Landmarks and Measurements

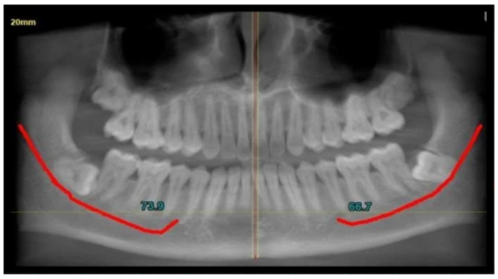
The mandibular canal was evaluated bilaterally for the following parameters:

1. Position of the mandibular canal in relation to the surrounding anatomical landmarks.
2. Diameter and length of the mandibular canal.
3. Horizontal and vertical location of the canal within the mandible.
4. Relationship of mandibular roots to the mandibular canal.
5. Length of the anterior loop of the mental nerve.
6. Morphological variations of the mandibular canal, including bifid or trifid canals.

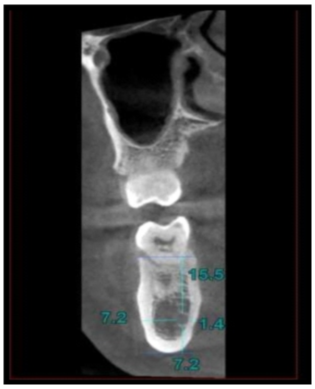
Measurements were recorded at standardized reference points, including the mandibular foramen, mental foramen, and intermediate canal regions. Distances between the mandibular canal and adjacent anatomical structures, such as the alveolar crest, buccal and lingual cortical plates, and root apices, were noted.



Measurement of Maximum Vertical & Horizontal Diameter of MC

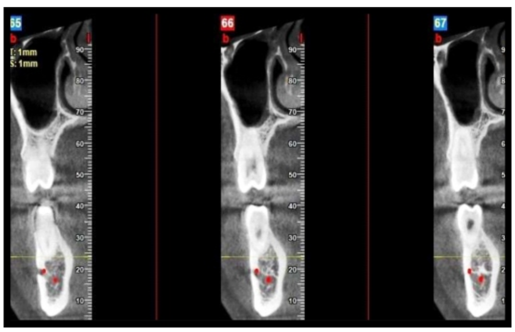



Measurement of Length of the Mandibular canal

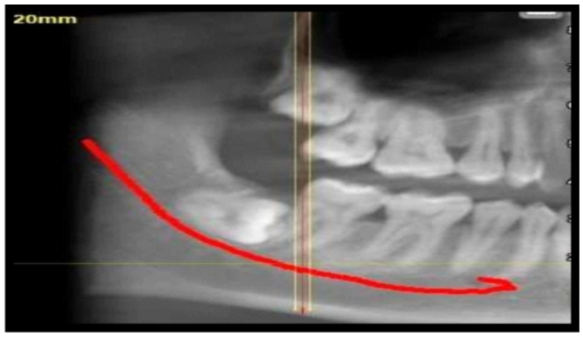



Location of MC – distance of MC from crestal bone level, inferior border of mandible, buccal & lingual cortical plate

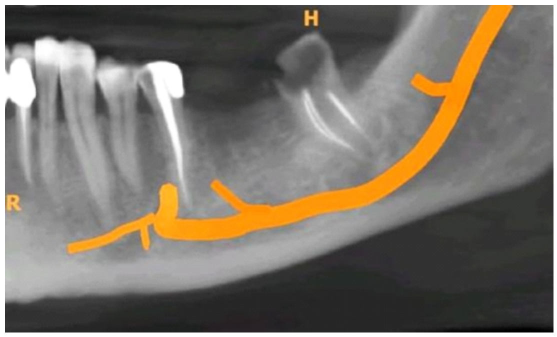

Measurement of distance between the root tip & upper border of MC



Measurement of anterior loop




Morphology of MC - Presence of single canal




Morphology of MC -Presence of bifid canal

### Data Recording and Analysis

All measurements were performed by trained observers using calibrated digital tools available in the CBCT software. Each parameter was measured twice, and the mean of the two readings was considered for analysis to minimize intra-observer variability. Data were tabulated and analyzed to identify variations in mandibular canal morphology and positioning across the study population.

### Statistical Analysis

Collected data were compiled and subjected to statistical analysis using appropriate software. Descriptive statistics, including mean and standard deviation, were calculated for continuous variables. Comparative analyses were performed where applicable to assess variations in mandibular canal anatomy across different sides and regions of the mandible. A p-value of $<0.05$ was considered statistically significant.

### Results

The present study analyzed 100 cone-beam computed tomography (CBCT) scans to assess the morphometric characteristics and variations of the mandibular canal. All measurements were successfully obtained bilaterally in all cases.

### Position and Course of the Mandibular Canal

The mandibular canal was consistently identified extending from the mandibular foramen to the mental foramen on both sides. Variations in its course, including linear, curved, and irregular patterns, were observed. The majority of canals followed a gently curved path, while a smaller percentage exhibited bifid or trifid patterns [Ref].

### Diameter and Length of the Mandibular Canal

The mean diameter of the mandibular canal demonstrated variation along its course, with the greatest diameter typically noted in the posterior region and a gradual decrease anteriorly. The mean length of the mandibular canal showed minor variations between the right and left sides; however, these differences were not statistically significant ($p > 0.05$).

### Horizontal and Vertical Positioning

Analysis of the horizontal and vertical positioning of the mandibular canal revealed consistent anatomical relationships with adjacent structures. The canal was located closer to the lingual cortical plate in the posterior mandible and tended to shift buccally toward the anterior region. Vertically, the distance from the canal to the alveolar crest decreased progressively from posterior to anterior regions.

### Relationship with Mandibular Root Apices

The mandibular canal was most frequently positioned below the apices of the mandibular molars, with close proximity observed particularly in the second molar region. Contact or near contact between root apices and the canal was occasionally noted, emphasizing the importance of precise preoperative evaluation during endodontic and surgical procedures.

### Anterior Loop of the Mental Nerve

The anterior loop of the mental nerve was identified in a significant proportion of cases, with its mean length showing mild variability between sides. The presence of an anterior loop extended the neurovascular bundle anterior to the mental foramen, a finding of considerable clinical relevance in implant placement and surgical planning.

### Morphological Variations

In addition to the standard canal configuration, bifid and trifid mandibular canals were identified in a subset of scans. These variations, although less frequent, hold substantial surgical significance, as they may alter the expected location of the neurovascular bundle and increase the risk of intraoperative complications if unrecognized.

Overall, the study demonstrated a wide range of anatomical variations in the mandibular canal's course, size, position, and morphology. Most measurements showed no statistically significant differences between the right and left sides. However, clinically relevant variability was evident, highlighting the importance of individualized radiographic assessment using CBCT to enhance surgical safety and treatment planning.

## Discussion

A thorough understanding of the mandibular canal's anatomy and its variations is crucial in oral and maxillofacial procedures, particularly in implant placement, third molar extraction, endodontic surgery, and orthognathic interventions. The present study evaluated 100 cone beam computed tomography (CBCT) scans to analyze the morphometric characteristics and anatomical variations of the mandibular canal in a North Indian population. The findings revealed significant diversity in canal course, diameter, vertical and horizontal positioning, and relationship with mandibular structures, consistent with previous literature [Ref].

The mandibular canal, extending from the mandibular foramen to the mental foramen, typically follows a gentle curvature, but variations such as bifid and trifid canals were identified in a subset of cases. Such variations, although less frequent, are clinically significant as they may influence the course of the inferior alveolar nerve (IAN) and increase the risk of nerve injury during surgical procedures [Ref]. Several studies have documented similar findings, reporting bifid canal incidence ranging from 0.08% to 65%, depending on the population studied and the imaging modality used [Ref]. This variability underscores the importance of population-specific studies in improving clinical decision making.

The mean diameter and length of the mandibular canal showed mild variability but remained largely consistent between the right and left sides. This symmetry aligns with earlier studies, which also observed minimal side to side differences [Ref]. However, the observed gradual reduction in canal diameter from posterior to anterior regions has clinical implications. Narrower anterior regions may increase the risk of nerve injury during implant placement in the premolar and canine areas if precise imaging and planning are not undertaken [Ref].

The horizontal and vertical positioning of the mandibular canal relative to surrounding anatomical landmarks is a critical consideration during surgical procedures. In the present study, the canal was located closer to the lingual cortical plate posteriorly and shifted buccally toward the anterior region. Vertically, the distance from the canal to the alveolar crest decreased anteriorly. These observations are consistent with previous reports and highlight the dynamic course of the canal within the mandibular body [Ref]. The proximity of the canal to root apices, particularly those of the second molar, further emphasizes the need for detailed preoperative imaging to prevent inadvertent nerve damage during endodontic or extraction procedures.

One of the clinically significant findings of this study was the identification of the anterior loop of the mental nerve in a considerable number of cases. The length of this loop varied slightly between sides, and its presence extended the neurovascular bundle anterior to the mental foramen. These findings are in agreement with previous studies that reported anterior loop lengths ranging from 0.5 mm to over 5 mm [Ref]. Unrecognized anterior loops may lead to nerve injury during implant placement or other surgical procedures in the premolar region, highlighting the importance of preoperative assessment.

The use of CBCT in this study allowed for detailed three dimensional visualization of the mandibular canal and associated structures, overcoming many limitations of traditional two dimensional imaging. CBCT provided accurate measurements of canal position, diameter, and relationship with surrounding landmarks, and facilitated the identification of anatomical variations that may not be visible on panoramic or periapical radiographs [Ref]. Previous studies have emphasized the superiority of CBCT in identifying bifid canals, anterior loops, and other variations, supporting its routine use in preoperative evaluation [Ref].

Population based differences in mandibular canal morphology have been reported in several studies, with variations attributed to genetic, ethnic, and environmental factors [Ref]. The present study's findings in a North Indian population contribute valuable region specific data, which is essential for improving clinical outcomes and minimizing complications in implantology and oral surgery. Understanding these differences enables clinicians to anticipate anatomical variations and adjust treatment planning accordingly.

While the study provides significant insights, certain limitations must be acknowledged. As a retrospective analysis, the study was limited by the availability and quality of archived CBCT scans. Additionally, the absence of clinical correlation data, such as postoperative outcomes or intraoperative findings, restricts the ability to fully assess the clinical impact of the observed variations. Future studies with larger sample sizes and multicenter participation are recommended to validate these findings and explore their clinical significance further.

In conclusion, the present study reinforces the importance of detailed assessment of mandibular canal morphology and variations in preoperative planning. The observed differences in canal course, diameter, positioning, and anterior loop length highlight the need for individualized evaluation of each patient. CBCT remains an indispensable imaging modality, offering accurate and comprehensive visualization of the mandibular canal and associated structures. By incorporating such detailed anatomical assessments into clinical practice, dental professionals can enhance surgical safety, reduce the risk of iatrogenic injuries, and improve patient outcomes.

## Conclusion

Within the limitations of this study, it can be concluded that the mandibular canal exhibits considerable anatomical variability in its course, diameter, position, and relationship with surrounding structures. The presence of bifid or trifid canals and variations in the anterior loop of the mental nerve highlight the importance of individualized preoperative assessment. These findings underscore the need for clinicians to thoroughly evaluate mandibular anatomy prior to implant placement, endodontic procedures, surgical interventions, and local anesthesia administration to minimize the risk of iatrogenic injuries.

Cone beam computed tomography (CBCT) proves to be an indispensable imaging modality, offering precise three-dimensional visualization of the mandibular canal and associated structures. Its ability to accurately depict canal morphology and anatomical relationships enhances diagnostic accuracy and surgical planning. Furthermore, the region-specific data generated by this study contribute valuable information to the existing literature and emphasize the significance of considering population based anatomical variations in clinical decision making. Incorporating such detailed assessments into clinical practice will ultimately improve surgical safety, optimize treatment outcomes, and enhance patient care.

## References

1. Lindh C, Petersson A, Klinge B. Measurements of distances related to the mandibular canal in radiographs. Clin Oral Implants Res 1995; 6 (2): 96-103.
2. Xie Q, Wolf J, Soikkonen K, Ainamo A. Height of mandibular basal bone in dentate and edentulous subjects Acta Odontol Scand 1996; 54(6): 379–383
3. Ramesh AS, Rijesh K, Sharma A, Prakash R, Kumar A, Karthik. The prevalence of mandibular incisive nerve canal and to evaluate its average location and dimension in Indian population. J Pharm Bioallied Sci 2015; 7: S594-6.
4. Leite GM, Lana JP, de Carvalho Machado V, Manzi FR, Souza PE, Horta MC. Anatomic variations and lesions of the mandibular canal detected by cone beam computed tomography. SurgRadiol Anat 2014; 36 (8): 795-804.
5. Rashsuren O, Choi JW, Han WJ, Kim EK. Assessment of bifid and trifid mandibular canals using cone beam computed tomography. Imaging Sci Dent. 2014; 44: 229-36.
6. Jung YH, Cho BH. Radiographic evaluation of the course and visibility of the mandibular canal. Imaging Sci Dent 2014; 44 (4): 273–278.
7. Sekerci AE, Sahman H. Cone Beam Computed Tomographic Analyses of the Position and Course of the Mandibular Canal: Relevance to the Sagittal Split Ramus Osteotomy. Bio Med Res Int 2014; 2: 1-11.
8. Velázqueza FA, Quilezb JB, Guerreroc FM, Arcosc PN, Alfarob FH, Padrósd EF et al. Reliability of cone beam computed tomography in locating and measuring the mandibular canal for planning of surgical techniques in the mandibular body. Rev Esp Cir Maxillofac 2015; 37: 182-187.
9. Haas LF, Dutra K, Porporatti AL, Mezzomo LA, De Luca Canto G, FloresMir C. Anatomical variations of mandibular canal detected by panoramic radiography and CT: a systematic review and meta-analysis. Dentomaxillofac Radiol 2016; 45 (2): 2015 - 30.
10. Safaee A, Mirbeigi M, Ezoddini F, Khojastepour L, Azam AN. Buccolingual course of the inferior alveolar canal in different mental foramen locations: A cone beam computed tomography study of an Iranian population, Int J Appl Basic Med Res. 2016; 6 (4): 262–266.
11. Mirbeigi S, Kazemipoor M, Khojastepour L. Evaluation of the Course of the Inferior Alveolar Canal: The First CBCT Study in an Iranian Population Pol J Radiol 2016; 81: 338–341.
12. Hiremath H, Agarwal R, Hiremath V, Phulambrikar T. Evaluation of proximity of mandibular molars and second premolar to inferior alveolar nerve canal among central Indians: A cone beam computed tomographic retrospective study. Indian J Dent Res 2016; 27: 312-316.
13. Koivisto T, Chiona D, Laura MSL, Scott BMS, Clanahan MC, Ahmad MM et al. Mandibular Canal Location: Cone-beam Computed Tomography Examination. J Endod 2016; 42

(7): 1018-1021.
14. Miles MS, ParksET, EckertGJ, Blanchard SB. Comparative evaluation of mandibular canal visibility on cross-sectional cone beam CT images: A retrospective study. DentoMaxillofacRadiol 2016; 45 (2): 296-300.
15. Munoz G, Dias FJ, Weber B, Betancourt P, Borie E. Anatomic relationships of mandibular canal- A cone beam CT study. Int J Morphol 2017; 5(4): 1243-1248.
16. Afsa M, Rahmati H. Branching of mandibular canal on cone beam computed tomography images. Singapore Dent J 2017; 38: 21-25.
17. Khorshidi H, Raoofi S, Ghapanchi J, Shahidi S, Paknahad M. Cone Beam Computed Tomographic Analysis of the Course and Position of Mandibular Canal. J Maxillofac Oral Surg 2017 Sep; 16 (3): 306–311.
18. Edrees AMF, Attia MA, Elsattar AMF, Gobran FHG, Ahmed IA. Course and Topographic Relationships of Mandibular Canal: A Cone Beam Computed Tomography Study. Int J Dentistry Oral Sci 2017; 4 (3): 444-449.
19. Khijmatgar S, Chowdhury C, Rao K, Thankappan S, Krishna NJ. Is there a justification for cone beam computed tomography for assessment of proximity of mandibular first and second molars to the inferior alveolar canal: A systematic review. Oral Sci Rehab. 2017; 3 (4): 48–56.
20. Juodzbalys G, Wang HL, Sabalys G. Anatomy of mandibular vital structures. Part I: mandibular canal and inferior alveolar neurovascular bundle in relation with dental implantology. J Oral Maxillofac Res 2017; 8: 34-39.
21. Meshram S, Gattani D, Shewale A, Gudadhe B, Dhuldhwaj R. Assessment of Inferior Alveolar Nerve Canal Position and Accessory Mental Foramen Using CBCT to Overcome Surgical Complication. Open Access Library Journal 2017; 4: 3609.
22. Haghanifar S, Moudi E, Bijani A, Lavasani S, Lameh A. Mandibular canal and its incisive branch: A CBCT study. World Family Medicine. 2017; 15 (8): 133140.
23. Vieira CL, Veloso SDAR, Lopes FF. Location of the course of the mandibular canal, anterior loop and accessory mental foramen through cone-beam computed tomography. SurgRadiolAnat 2018; 40: 1411-1417.
24. do Carmo Oliveira M, Tedesco TK, Gimenez T, Allegrini S Jr. Analysis of the frequency of visualization of morphological variations in anatomical bone features in the mandibular interforaminal region through cone beam computed tomography. SurgRadiol Anat 2018; 40: 1119-1131.
25. Aksoy U, Aksoy S, Orhan K. A cone-beam computed tomography study of the anatomical relationships between mandibular teeth and the mandibular canal, with a review of the current literature. Microsc Res Tech 2018; 81: 308-314.
26. Chaudhary ML, Anchalia S, Sharma V. Evaluation of Inferior Alveolar Canal and its Variations using Cone Beam CT-scan. Int J Anat RadiolSurg 2018; 7(1): 15-20.
27. de Oliveira-Santos C, Souza PH, de Azambuja Berti-Couto S, Stinkens L, Moyaert K, Rubira-Bullen IR et al. Assessment of variations of the mandibular canal through cone beam computed tomography. Clin Oral Investig 2018; 16(2): 387-93.
28. Komal A, Bedi RS, Wadhwani P, Aurora JK, Chauhan H. Study of Normal Anatomy of Mandibular Canal and its Variations in Indian Population Using CBCT. J Maxillofac Oral Surg 2020; 19: 98-105.
29. Goller Bulut D, Köse E. Available bone morphology and status of neural structures in the mandibular interforaminal region: three dimensional analysis of anatomical structures. SurgRadiol Anat 2018; 40: 1243-1252.
30. Nair UP, Yazdi MH, Nayar GM, Parry H, Katkar RA, Nair MK. Configuration of the inferior alveolar canal as detected by cone beam computed tomography. J Conserv Dent 2018; 16: 518-21.
31. Oliveira-Santos C, Capelozza ALA, Dezzoti MSG, Fischer CM, PoletiMl, Rubira-Bullen IRF. Visibility of the mandibular canal on CBCT cross-sectional images. J Applied Oral Sci 2019; 19 (3): 240-243.
32. Kalabalik F, Aytugar E. Localization of the Mandibular Canal in a Turkish Population: a Retrospective Cone-Beam Computed Tomography Study. J Oral Maxillofac Res 2019; 10 (2): e24-28.
33. Alabdulwahid A, Alfaleh W. Identification of mandibular canal in cone beam computed tomography plane with different voxel sizes. Saudi Dent J. 2020 Dec; 32 (8): 403-409.
34. Tulio Manfron AP, Ditzel AS, Ignácio SA, Fontão FN, Azevedo-Alanis LR. Assessment of the configuration of the mandibular canal using cone beam computed tomography. Minerva Stomatol 2020; 69: 377-383.
35. Pria CM, Masood F, Beckerley JM, Carson RE. Study of inferior alveolar Canal and Mental Foramen on Digital Panoramic Images J Contemp Dent Pract 2021; 12: 265-271.
36. Balaji SM, Krishnaswamy NR, Kumar SM, Rooban T. Inferior alveolar nerve canal position among South Indians: A cone beam computed tomographic pilot study. Ann Maxillofac Surg 2022; 2: 51-55.
37. Shan S, Zhong S, Li J, Wang T. Systematic review and meta-analysis of mandibular canal variations on cone beam computed tomography. Oral Radiol 2022; 38: 445-451.
38. Al-Juboori MJ, Yuen KY, Hua CM, Tawfiq OF, Al-Wakeel HA. Inferior Alveolar Nerve Location to Determine Zone of Safety for Dental Implant Placement among Malaysian Population. J Dent Oro Surg 2016; 1(2): 108-112.
39. Chakraborty R, Panchbhai A, Bhowate RR, Sen S. Comparison between Conventional Radiography and 3D Volumetric Imaging for Location of Mandibular Canal: In Vivo Study. J Indian Acad Oral Med Radiol 2017; 29: 267272.
40. Bartling R, Freeman K, Kraut RA. The incidence of altered sensation of the mental nerve after mandibular implant placement. J Oral MaxillofacSurg 1999; 57: 1408–1412.

41. Komar D, Lathrop S. Frequencies of morphological characteristics in two contemporary forensic collections: Implications for identification. J Forensic Sci 2006; 51: 974-978.
42. Neiva RF, Gapski R, Wang HL. Morphometric analysis of implant related anatomy in Caucasian skulls. J Periodontol 2004; 75: 1061-1067.
43. Kamburoglu K, Kiliç C, Özen T, Yüksel SP. Measurements of mandibular canal region obtained by cone beam computed tomography: a cadaveric study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009; 107: e34-e42.
44. Nkenke E, Radespiel-Troger M, Wiltfang J, Schultze-Mosgau S, Winkler G, Neukam FW. Morbidity of harvesting of retromolar bone grafts: a prospective study. Clin Oral Implants Res 2002; 13: 514-21.
45. Aglarci OS, Güngör E, Altunsoy M, Nur B, OK E. Three-Dimensional Analysis of Mandibular Foramen Location: A Cone Beam Computed Tomography Study. OMICS J Radiol 2015; 4: 179-183.
46. Parnia F, MoslehifardE, HafezeqoranA, MahboubF, Kahnamoui MH. Characteristics of anatomical landmarks in the mandibular interforaminal region: a cone beam computed tomography study. Med Oral Patol Oral Cir Bucal 2012; 17 (3): 420-425.
47. Velasco-Torres M, Padial-Molina M, Avila-Ortiz G, García-Delgado R, Catena A, Galindo-Moreno P. Inferior alveolar nerve trajectory, mental foramen location and incidence of mental nerve anterior loop. Med Oral Patol Oral Cir Bucal 2017 22 (5): e630-635.
48. Cartes G, Garay I, Deana NF, Navarro P, Alves N. Mandibular Canal Course and the Position of the Mental Foramen by Panoramic X-Ray in Chilean Individuals. Bio Med Res Int 2018; 10.
49. Levine MH, Goddard AL, Dodson TB. Inferior alveolar nerve canal position: a Clinical and radiographic study. J Oral MaxillofacSurg 2007; 65: 470-474.
50. Simonton JD, Azevedo B, Schindler WG, Hargreaves KM. Age and gender related differences in the position of the inferior alveolar nerve by using cone beam computed tomography. J Endod. 2009; 35: 944-949.
51. Chong BS, Quinn A, Pawar RR, Makdissi J, Sidhu SK. The anatomical relationship between the roots of mandibular second molars and the inferior alveolar nerve. Int Endod J 2014; 48 (6): 1-7.
52. Kim ST, Hu KS, Song WC, Kang MK, Park HD, Kim HJ. Location of the mandibular canal and the topography of its neurovascular structures. J Craniofac Surg 2009; 20: 936–939.
53. Iyengar AR, Patil S, Nagesh KS, Mehkri S, Manchanda A. Detection of anterior loop and other patterns of entry of mental nerve into the mental foramen: a radiographic study in panoramic images. J Dental Implants 2013; 3: 21-26.
54. Apostolakis D, Brown JE. The anterior loop of the inferior alveolar nerve: Prevalence, measurement of its length and a recommendation for interforaminal implant installation based on cone beam CT imaging. Clin Oral Implants Res 2011; 23: 1022-1030.
55. Nakib LHA, Rasul SK. Evaluation of the anterior loop of the mental nerve incidence and extension in different age groups in Sulaimania city using digital panoramic imaging system. J Coll Dent Univ Baghdad 2013; 25: 99-104.
56. Kaya Y, Sencimen M, Sahin S, Okcu KM, Dogan N, Bahcecitapar M. Retrospective radiographic evaluation of the anterior loop of the mental nerve:Comparison between panoramic radiography and spiral computerized tomography. Int J Oral Maxillofac Implants 2008; 23: 919-925.
57. Vujanovic-Eskenazi A, Valero-James JM, Sánchez-Garcés MA, Gay-Escoda C. A retrospective radiographic evaluation of the anterior loop of the mental nerve: Comparison between panoramic radiography and cone beam computerized tomography. Med Oral Patol Oral Cir Bucal 2014; 43: e217-222.
58. Couto-Filho CEG, Moraes PH, Alonso MBC, Haiter-Neto F, Olate S, Albergaria-Barbosa JR. Accuracy in the diagnosis of the position of the mental nerve loop. A comparative study between panoramic radiography and cone beam computed tomography. Int J Morphol 2015; 33: 327-332.
59. Verner FS, Visconti MAP, Martin MT, Devito KL, Assis NM, Ribeiro CG. Development of Estimation Models of Bone Height Considering the Potential Presence of Anterior Extension of the Mandibular Canal. Implant Dent 2015; 24: 192-196.
60. Eren H, Orhan K, Bagis N, Nalcaci R, Misirli M, Hincal E et al. Cone beam computed tomography evaluation of mandibular canal anterior loop morphology and volume in a group of Turkish patients. Biotechnology & Biotechnological Equipment 2016; 30 (2): 346-353.
61. Nascimento EHL, Pereth MLD, Perez FMD. Assessment of the anterior loop of the mandibular canal: A study using cone-beam computed tomography. Imaging Sci Dent 2016; 46 (2): 69-75.
62. Kuzmanovic DV, Payne AG, Kieser JA, Dias GJ. Anterior loop of the mental nerve: a morphological and radiographic study. Clin Oral Implants Res 2003; 14(4): 464-471.
63. Phraisukwisarn P, Asvanund P, Kretapirom K. Measurement of anterior loop of inferior alveolar nerve using cone beam computed tomography (CBCT). Med Dent J 2017; 37: 81-87.
64. Kheir MK, Sheikhi M. Assessment of the anterior loop of mental nerve in an Iranian population using cone beam computed tomography scan. Dent Res J 2017; 14: 418-422.

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# Condylar Osseous Changes in Bruxism Patients: A CBCT Assessment of Symptomatic vs. Asymptomatic Temporomandibular Joints in an Indian Cohort

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## Abstract

**Objectives:** Temporomandibular joint disorders (TMDs), characterized by orofacial pain and functional limitations, are linked to degenerative condylar osseous changes like flattening, erosion, osteophytes, and sclerosis. Bruxism, an excessive jaw activity, is a primary contributing factor, exerting supraphysiologic forces on the TMJ. Given the diagnostic advantages of Cone Beam Computed Tomography (CBCT) and limited specific data in India, this cross-sectional observational study, conducted from March 2023 to March 2024, aimed to evaluate and correlate condylar alterations in 60 Indian bruxism patients (aged 18-35), comparing symptomatic (n=30) and asymptomatic (n=30) TMD groups using CBCT. Symptomatic patients exhibited significantly higher VAS scores (5.7±1.35 vs. 1.2±0.68; $p<0.05$).

**Results:** Overall osseous changes differed significantly between groups ($p=0.002$), with flattening and sclerosis more prevalent in symptomatic cases, while osteophytes and erosion appeared proportionally higher in asymptomatic individuals. A highly significant side wise difference was noted ($p=0.001$), but no significant gender difference was found ($p=0.06$).

**Conclusions:** This study confirms bruxism's association with distinct condylar osseous changes detectable by CBCT, highlighting its value for early detection and intervention to mitigate TMJ degeneration.

**Keywords:** Bruxism Temporomandibular Joint Disorders (TMDs) Cone-beam Computed Tomography (CBCT) Condylar Osseous Changes Orofacial Pain.

## Introduction

Temporomandibular joint disorders (TMDs) represent a complex and prevalent subset of musculoskeletal conditions primarily characterized by chronic non-odontogenic orofacial pain and functional limitations [1]. These disorders encompass a spectrum of clinical issues affecting the intricate temporomandibular joint (TMJ) apparatus, associated masticatory musculature, and adjacent neurovascular structures, collectively leading to significant patient discomfort and impaired oral function [2]. Diagnostic indicators and symptomatic presentations of TMDs commonly include temporomandibular arthralgia, myofascial tenderness, restricted mandibular range of motion, and articular disc displacement manifested as clicking or crepitation sounds [3]. The chronic nature of TMDs profoundly impacts an individual's quality of life, extending beyond localized pain to affect masticatory efficiency, speech articulation, and overall psychosocial well being [4].

The pathological progression of TMDs is frequently correlated with discernible degenerative osseous changes within the TMJ condyle. These alterations include, but are not limited to, condylar flattening, cortical surface erosion, osteophyte formation, increased subchondral bone density (sclerosis), and the development of intraosseous pseudocysts [5]. Such structural modifications are considered pivotal in the initiation and chronic evolution of TMJ degenerative joint disease (TMJ-DJD) and often demonstrate a direct relationship with the severity of reported clinical symptoms. Consequently, the precise identification and comprehensive

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characterization of these osseous changes are fundamental for accurate diagnosis of TMJ dysfunction and for guiding the formulation of evidence based, individualized treatment strategies. Orofacial pain, broadly conceptualized as algia localized to the facial region superior to the neck and anterior to the auricular structures, commonly presents as a persistent or recurrent condition originating from dysfunctions within diverse surrounding anatomical structures. Contemporary epidemiological data estimate the global prevalence of orofacial pain in the general population to range between 7% and 26% [6]. The multifaceted etiology of orofacial pain frequently presents considerable diagnostic and management complexities, necessitating a meticulous patient history, comprehensive clinical examination, and often, advanced diagnostic imaging. Within the broad spectrum of TMD related symptomatology, orofacial pain remains the most frequently reported complaint, significantly affecting patient functionality and overall well being [11].

Bruxism, characterized by repetitive masticatory muscle activity involving forceful clenching or grinding of the teeth, without overt functional purpose, has been robustly implicated as a significant etiological and exacerbating factor in the development of TMDs. This parafunctional activity is mechanistically categorized into awake bruxism (AB), which occurs during diurnal periods and is frequently exacerbated by psychological stress or focused attention, and sleep bruxism (SB), which is classified as a sleep related movement disorder occurring during nocturnal sleep cycles. Both forms of bruxism generate supraphysiologic occlusal and articular forces, thereby predisposing the TMJ and masticatory musculature to pathological structural adaptations and an increased susceptibility to joint disorders. Recent research underscores a complex, bidirectional interrelationship between bruxism, psychological stress, and compromised sleep architecture, collectively contributing to the perpetuation of TMD symptoms. Furthermore, intrinsic host factors such as age, biological sex, and genetic polymorphisms have been identified as crucial modulators influencing bruxism prevalence and its phenotypic expression. As a highly prevalent oral parafunctional habit, bruxism exerts substantial and often deleterious biomechanical impacts on the physiological health and structural integrity of the TMJ and its contiguous components.

The foundational concept of "parafunction" was first articulated by Drum in 1972, serving to delineate abnormal occlusal stress resulting from non-functional oral activities from the physiological forces generated during mastication. Non-functional oromandibular behaviors, including habitual teeth clenching, lip and cheek biting, onychophagia, and tongue thrusting, contribute to TMD pathogenesis by imposing chronic and sustained biomechanical loading on the TMJ and its surrounding musculature. The historical evolution of terminology from "bruxomania," coined by Marie Pietkiewicz in 1907, to the contemporary "bruxism," meticulously describes the habitual, non-functional grinding and clenching of teeth. The intense and repetitive forces generated during bruxism can accelerate the adaptive and maladaptive remodeling processes within the TMJ, potentially culminating in degenerative joint disorders over protracted periods. Longitudinal cohort studies and systematic reviews consistently demonstrate that individuals with chronic bruxism exhibit a significantly heightened risk of developing characteristic TMD symptomatology, including arthralgia, restricted mandibular opening, and audible articular sounds. Consequently, the imperative for early detection and targeted intervention for bruxism is paramount to prevent the progressive deterioration of TMJ integrity and function.

The mandibular condyle, as a pivotal anatomical component of the TMJ, is indispensable for complex mandibular kinematics and exhibits considerable morphological heterogeneity across diverse age demographics. Pathological structural changes within the condyle can arise from a multitude of etiological factors, including malocclusion, traumatic injuries, and chronic TMD processes. These osseous alterations, manifesting as condylar flattening, cortical surface erosion, osteophyte formation, and sclerosis, are precisely detectable and quantifiable through advanced radiographic imaging modalities.

While conventional two-dimensional (2D) imaging techniques, such as panoramic radiographs and TMJ specific plain X-rays, have been historically employed for the initial screening of TMJ disorders , their inherent limitations, including anatomical superimposition and geometric distortions, compromise their diagnostic accuracy in detecting subtle condylar changes. Conversely, advanced three dimensional (3D) imaging modalities, such as conventional computed tomography (CT) and magnetic resonance imaging (MRI), offer superior spatial resolution and detailed visualization of both hard and soft tissues within the TMJ complex. CT scans provide exquisite detail regarding osseous structures, whereas MRI is indispensable for assessing soft tissue abnormalities, including articular disc displacement and joint effusion. Despite their undeniable diagnostic advantages, conventional CT and MRI are associated with higher ionizing radiation exposure (for CT) and greater economic cost, thereby restricting their widespread routine application in contemporary dental practice.

Cone beam computed tomography (CBCT) has emerged as a highly promising and increasingly utilized alternative for comprehensive TMJ imaging, primarily attributable to its relatively lower ionizing radiation dose, superior spatial resolution, and enhanced cost effectiveness. CBCT facilitates the precise and volumetric evaluation of condylar morphology and internal osseous architecture, enabling the early detection of subtle degenerative changes within the TMJ. Numerous recent investigations have rigorously explored the radiographic characteristics of temporomandibular joint osteoarthritis (TMJOA) utilizing CBCT. Research findings consistently indicate that bruxism patients frequently exhibit significant reductions in mandibular surface area, coupled with discernible structural alterations in both the condyle and coronoid process, which can be visualized with CBCT. These specific structural modifications detected by CBCT may serve as critical early indicators of impending TMJOA, thereby emphasizing the clinical imperative for timely diagnosis and intervention before symptomatic progression.

Given the existing paucity of contemporary studies that have specifically utilized CBCT to comprehensively assess condylar osseous changes in bruxism patients across symptomatic and asymptomatic cohorts, this investigation aims to establish a robust correlation between bruxism induced biomechanical stress and TMJ structural alterations. By meticulously analyzing high resolution CBCT images obtained from individuals with both symptomatic and asymptomatic TMJ presentations of bruxism, we anticipate deriving novel insights into the initiation, progression, and early detection of joint degeneration. Such insights are crucial for refining diagnostic protocols and facilitating the development of more targeted and effective therapeutic strategies. Ultimately, the early and accurate identification of these osseous changes holds significant potential for preventing severe TMJ dysfunction, thereby substantially improving long-term patient outcomes and overall quality of life.

## Materials and Methods

### Materials

### Study Design and Setting

This investigation employed a cross-sectional observational study design to assess condylar osseous changes.

### Participants

The study cohort comprised 60 individuals formally diagnosed with bruxism, from whom CBCT images of their TMJ condyles were analyzed. Participants were recruited from the National Capital Region (NCR) of India. To ensure homogeneity within the study population concerning age related physiological changes, all included subjects were rigorously selected within a narrow age range of 18 to 35 years. A non-probabilistic consecutive sampling method was utilized, whereby all individuals who presented to the department and fulfilled the predefined eligibility criteria were sequentially enrolled until the requisite sample size was achieved. Prior to any study procedures, ethical clearance was formally obtained from the Institutional Ethical Committee of the college.

Comprehensive informed written consent was secured from each participant after a thorough explanation of the study objectives, procedures, potential risks, and benefits. All collected demographic and clinical data were meticulously recorded in a standardized, structured proforma.

Eligibility for participation was strictly governed by a set of inclusion and exclusion criteria. Individuals aged between 18 and 35 years were included, provided they exhibited no pre-existing pathological lesions unequivocally identified within the mandible or maxilla. Furthermore, the availability of diagnostic quality CBCT images of both mandibular condyles, demonstrating adequate density, contrast, and anatomical coverage for comprehensive assessment, was a prerequisite. Finally, all participants were required to provide voluntary agreement and informed written consent to participate in the study protocol. Conversely, subjects were excluded if their CBCT images were obtained from individuals younger than 18 years or older than 35 years. A history of previous orthognathic surgical procedures, documented condylar fractures, or any significant craniofacial trauma that could inherently alter TMJ morphology or function also led to exclusion. The presence of systemic inflammatory or autoimmune diseases known to impact bone metabolism or joint integrity, including but not limited to rheumatoid arthritis, Sjögren's syndrome, reactive arthritis, or systemic lupus erythematosus, constituted an exclusion criterion. Similarly, CBCT scans of individuals presenting with gross facial asymmetry or confirmed developmental abnormalities of the condyle (e.g., condylar hyperplasia or hypoplasia) were excluded. Images exhibiting suboptimal resolution, motion artifacts, or insufficient clarity that would preclude accurate radiographic interpretation were not utilized. Participants with a history of any neoplastic processes (benign or malignant tumors/growths) within the orofacial region that could intrinsically affect condylar morphology or joint space dimensions were excluded, as were patients with diagnosed nutritional deficiencies known to impact bone health, specifically vitamin D and calcium deficiencies. Finally, pregnant individuals were excluded due to potential radiation exposure concerns.

Following the diagnostic assessment for bruxism and TMJ symptomatology, the 60 participants were rigorously categorized into two distinct groups to facilitate comparative analysis. Group A, designated as the Symptomatic Study Group, comprised 30 individuals diagnosed with bruxism who concomitantly experienced symptomatic TMDs, primarily characterized by subjective reports of joint pain, objectively validated by specific clinical assessment criteria. This group included 12 males and 18 females. Group B, serving as the Asymptomatic Control Group, also consisted of 30 individuals diagnosed with bruxism but who reported no symptomatic TMDs, specifically lacking any associated joint pain. This group included 11 males and 19 females.

### Diagnostic Criteria for Bruxism (Non-Instrumental Approach)

The presence of bruxism in all participants was ascertained using a non-instrumental diagnostic approach, rigorously adapted from the international consensus on the assessment of bruxism as outlined by Lobbezoo et al.

A structured questionnaire was administered to each participant, encompassing five key items designed to elicit self-reported bruxism behaviors. These items included inquiries regarding self-awareness of sleep grinding ("Are you aware that you grind your teeth while sleeping?"), observer reported sleep grinding ("Has anyone (e.g., a bed partner) informed you that you grind your teeth while sleeping?"), self-reported sleep clenching ("Have you ever noticed that your jaws feel tense, protruded, or clenched when you wake up in the morning or during the night?"), self reported awake clenching ("Do you clench your teeth while awake?"), and self-reported awake grinding ("Do you grind your teeth while you are awake?"). Participants provided dichotomous ("Yes" or "No") responses to each question. Subsequent to the questionnaire, a single, calibrated, qualified professional conducted a comprehensive clinical examination to objectively confirm the self-reported signs and symptoms consistent with bruxism. A definitive clinical diagnosis of bruxism was established upon the convergence of self-reported data and specific objective clinical findings. Confirmation of sleep grinding was based on the presence of characteristic wear facets or enamel loss on the occlusal and/or incisal surfaces of anterior and posterior teeth, serving as objective evidence of a chronic grinding habit. Observer reported sleep grinding was considered positively confirmed if a bed partner or a close observer consistently reported audible tooth grinding on at least three distinct nights per week. The diagnosis of sleep clenching was made if at least two of the following objective clinical findings were concurrently present: pain or tenderness elicited upon bilateral palpation of the masseter muscles; observable hypertrophy of the masseter muscle, assessed visually and by palpation during clinical evaluation; or the presence of distinct lateral tongue indentations (scalloped tongue), indicative of chronic tongue bracing against the lingual aspects of the teeth during clenching. The clinical criteria for confirming awake teeth or jaw clenching were analogous to those employed for sleep clenching, requiring the presence of at least two of the aforementioned objective clinical findings. Finally, awake grinding was confirmed if the patient reported conscious awareness of teeth grinding during wakefulness, further corroborated by the presence of characteristic occlusal wear patterns consistent with those observed in sleep grinding cases.

### Assessment of Temporomandibular Dysfunction (TMD)

Symptoms To precisely differentiate between symptomatic and asymptomatic presentations of bruxism related TMJ disorders, a standardized assessment of TMJ pain was conducted. This involved extraoral palpation of the temporomandibular joint, applying consistent pressure to the lateral pole and posterior aspects of the condyle. The intensity of reported pain was quantitatively assessed using a Visual Analogue Scale (VAS), a 10-point psychometric scale where 0 represents no pain and 10 represents the worst imaginable pain. A VAS score of 3 or above was established as the objective threshold to define clinically symptomatic cases, indicating the presence of pain directly associated with the TMJ.

### Cone Beam Computed Tomography (CBCT)

Examination All eligible participants underwent a comprehensive CBCT imaging procedure to meticulously assess morphological and osseous changes within the temporomandibular joint. All CBCT scans were acquired using a NewTom GO 3D digital imaging system (NewTom S.p.A., Verona, Italy. Volumetric data obtained from the CBCT scans were subsequently analyzed across three primary orthogonal planes: the transverse plane (Xaxis), the coronal plane (Y-axis), and the sagittal plane (Z-axis). During image acquisition, each participant was carefully positioned within the CBCT machine's rotating gantry. To ensure optimal image quality and minimize motion artifacts, the patient's head was stabilized using a dedicated chin rest, head supports, and a bite block to maintain proper occlusal positioning and mandibular stability throughout the acquisition period. The technical specifications for CBCT imaging were standardized to ensure consistency and diagnostic quality. A restricted Field of View (FOV), specifically focused on the bilateral TMJ region, was employed to minimize patient radiation exposure while ensuring comprehensive coverage of both condyles and associated articular structures.

The imaging parameters utilized were as follows: a tube voltage of 90 kVp (kilovoltage peak), a tube current of 10 mA (milliamperes), a fine voxel size of 78  m (micrometers) to ensure high spatial resolution for intricate osseous detail, and an exposure time of 10 seconds. Raw projection data were reconstructed into axial crosssectional images using specialized dental computed tomography software, NNT Software (NewTom S.p.A., Verona, Italy), which provides dedicated tools for detailed dentomaxillofacial assessment. All CBCT images were subsequently reviewed by a single, experienced, and calibrated oral radiologist on a high-resolution 15.6-inch LCD screen under controlled ambient lighting conditions to ensure optimal contrast, brightness, and diagnostic visibility. A total of 120 CBCT images (representing 60 patients, with two condyles per patient) were systematically evaluated for the presence of osseous changes in the mandibular condyles, with assessment performed across both sagittal and coronal slices to capture comprehensive three dimensional morphology.

### Statistical Analysis

An independent t-test was used to analyze the correlation between various study parameters and gender. To evaluate the differences between the right and left TMJ sides, a paired t-test was applied. For all analyses, a 5% level of significance ($\alpha$=0.05) was chosen, and a p-value of less than 0.05 was considered statistically significant.

### Result

The present research systematically investigated condylar osseous changes in a cohort of 60 individuals diagnosed with bruxism. The study population comprised 23 males and 37 females. Participants were prospectively categorized into two distinct groups: Group A, consisting of 30 symptomatic individuals (12 males, 18 females) experiencing TMDs associated with bruxism, and Group B, comprising 30 asymptomatic individuals (11 males, 19 females) diagnosed with bruxism but without TMD symptomatology.

#### Age Distribution of Study Cohorts

The mean age for subjects in Group A was calculated as 25.73±2.62 years (mean ± standard deviation, SD), with individual ages ranging from 19 to 35 years. In Group B, the mean age was 26.24 ± 2.44 years, with an age range spanning 18 to 34 years. Across the entire study cohort of 60 participants, the overall mean age was determined to be 25.98±2.53 years, with a total age range of 18 to 35 years.

**Comparison of Mean Visual Analogue Scale (VAS) Scores**

A quantitative assessment of pain experience, as measured by the Visual Analogue Scale (VAS) scores, revealed a significant distinction between the two groups. Subjects in Group A (symptomatic) reported VAS scores ranging from 3 to 9, yielding an overall mean VAS score of 5.7±1.35. In stark contrast, subjects in Group B (asymptomatic) exhibited VAS scores ranging from 0 to 2, with an overall mean VAS score of 1.2±0.68. The observed difference in the mean VAS scores between Group A and Group B was found to be statistically significant ($p<0.05$), unequivocally demonstrating the symptomatic disparity between the cohorts.

**Prevalence of Osseous Changes in Condyles by Symptomatic Status**

The distribution of specific osseous changes observed in the mandibular condyles, assessed via CBCT, varied between the symptomatic and asymptomatic groups. In Group A (symptomatic subjects), sclerosis was the most prevalent osseous alteration, identified in 19 condyles (31.7% of condyles in Group A). This was closely followed by flattening, observed in 17 condyles (28.3%). Less frequently observed changes included osteophyte formation in 2 condyles (3.3%) and erosion in 1 condyle (1.7%). A normal condylar morphology was present in 21 condyles (35.0%) within this group. Conversely, in Group B (asymptomatic subjects), normal morphology was the most common finding, observed in 26 condyles (43.3% of condyles in Group B). Among osseous alterations, sclerosis was noted in 14 condyles (23.3%), and flattening in 11 condyles (18.3%). Osteophyte formation was more prevalent in the asymptomatic group, detected in 5 condyles (8.3%), as was erosion, identified in 4 condyles (6.7%). A statistical comparison of the distribution of these osseous changes between Group A and Group B demonstrated a statistically significant difference (Paired t-test value = 1.287, p=0.002), indicating distinct patterns of condylar alterations based on the presence or absence of TMJ symptoms in bruxism patients.

**Comparison of Osseous Changes in Condyles – Side-Wise**

Analysis An analysis of osseous changes based on the laterality of the TMJ (right versus left condyle) revealed significant differences. For the Right side condyles, sclerosis was the most frequently observed change, present in 18 condyles (30.0% of right-side condyles). This was followed by flattening in 12 condyles (20.0%), osteophyte formation in 3 condyles (5.0%), and erosion in 2 condyles (3.3%). Normal morphology was retained in 21 condyles (35.0%). For the Left side condyles, flattening was the most common finding, identified in 16 condyles (26.7% of left-side condyles). Sclerosis was present in 15 condyles (25.0%), osteophyte formation in 4 condyles (6.7%), and erosion in 3 condyles (5.0%). Normal morphology was observed in 26 condyles (43.3%) on the left side. The statistical comparison indicated a highly significant difference in the distribution of osseous changes between the right and left TMJ sides (Paired t-test value = 2.354, p=0.001). This suggests a distinct pattern of condylar remodeling or degeneration depending on the side of the mandible.

**Comparison of Osseous Changes in Condyles Gender Wise Analysis**

Among the male participants, sclerosis was the most prevalent finding, observed in 19 condyles (41.3% of male condyles). Flattening was present in 13 condyles (28.3%), while osteophyte formation and erosion were each identified in 2 condyles (4.3% respectively). Normal morphology was observed in 10 condyles (21.7%) among males. For female participants, normal morphology was the predominant finding, present in 37 condyles (50.0% of female condyles). Among osseous changes, flattening was noted in 15 condyles (20.3%), sclerosis in 14 condyles (6.8%), osteophyte formation in 5 condyles (8.3%), and erosion in 3 condyles (4.1%). It's important to note that the percentages presented for gender-wise comparison represent the proportion of affected condyles within each gender group (e.g., 13 out of 46 male condyles showed flattening, equating to 28.3%). A statistical analysis comparing the overall distribution of osseous changes between male and female participants yielded a non-statistically significant difference (Paired t-test value = -0.254, p=0.06). This suggests that, within the parameters of this study, gender did not exert a statistically significant influence on the overall prevalence patterns of these specific condylar osseous changes.

**Osseous Changes Observed in CBCT Scans**

CBCT imaging allowed for the precise and detailed evaluation and documentation of five specific categories of osseous alterations within the temporomandibular condyles. These classifications were based on established radiographic criteria for TMJ degenerative changes. The analysis was conducted across both corrected sagittal and coronal views, as illustrated in Figure 1.

Normal morphology was characterized by the complete absence of structural abnormalities, with the condylar region maintaining a smooth, intact, and well defined cortical contour, as demonstrated in the corrected sagittal view (Figure 1A) and the corrected coronal view (Figure 1B). Conversely, several pathological alterations were documented. Flattening, defined as a discernible loss of the normal convex or concave physiological contour of the condylar articular surface, was observed in both corrected sagittal (Figure 1C) and coronal (Figure 1D) views, indicating an adaptive or degenerative response to altered biomechanical loads. Osteophyte formation, characterized by the presence of localized bony outgrowths or spur formations originating from the mineralized articular surface of the condyle, was visible in the corrected sagittal view (Figure 1E) and corrected coronal view (Figure 1F), typically indicative of bone remodeling in response to increased stress or early degenerative jointdisease. Sclerosis was identified as a generalized or localized thickening and increase in radiodensity of the subchondral cortical bone along the articular surface, suggestive of increased bone density in response to chronic mechanical stress or early osteoarthritic changes, as shown in the corrected sagittal (Figure 1G) and coronal (Figure 1H) views. Finally, erosion was defined as the presence of localized, irregular areas of rarefaction or discontinuity within the cortical plate of the condylar surface, representing progressive degenerative changes and loss of osseous tissue, clearly seen in the corrected sagittal (Figure 1I) and coronal (Figure 1J) views.

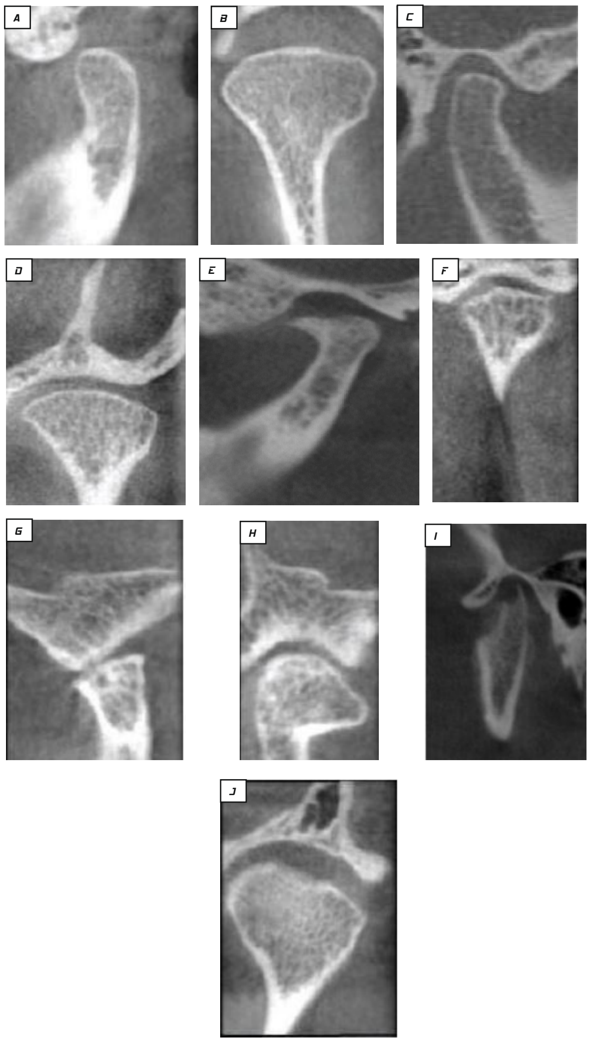


**Figure 1: Comprehensive visual guide to the condylar osseous changes evaluated in the study. A and B illustrate the normal condyle, presented in corrected sagittal and coronal views, respectively. Condylar flattening, a loss of the normal convex contour, is depicted in both a corrected sagittal view in panel C and a corrected coronal view in panel D. The presence of an osteophyte, a localized bony outgrowth, is shown in the corrected sagittal view in panel E and in the corrected coronal view in panel F. Sclerosis, or the thickening of cortical bone, with a sagittal view is shown in panel G and a coronal view in panel H. Finally, condylar erosion, characterized by rarefied areas within the cortical plate, is illustrated in a corrected sagittal view in panel I and a corrected coronal view in panel J.**

The present study meticulously aimed to evaluate the correlation between condylar osseous changes, as visualized by CBCT, in bruxism patients presenting with either symptomatic or asymptomatic TMJ conditions. The cohort of 60 subjects was systematically categorized into Group A (30 symptomatic patients) and Group B (30 asymptomatic patients), with both groups undergoing bilateral CBCT imaging of their condyles (totaling 120 condyles). The comprehensive analysis of these images revealed distinct patterns of osseous changes. In Group A (symptomatic), sclerosis was the most frequently observed change (31.7% of condyles), followed by flattening (28.3%). Osteophyte formation (3.3%) and erosion (1.7%) were less prevalent. Conversely, in Group B (asymptomatic), normal morphology predominated (43.3%), with sclerosis (23.3%) and flattening (18.3%) also observed. Intriguingly, osteophyte formation (8.3%) and erosion (6.7%) were proportionally more prevalent in the asymptomatic group than in the symptomatic group. This observation for osteophytes and erosion in asymptomatic individuals may suggest that these changes represent early adaptive remodeling processes that can occur prior to the onset of overt clinical symptoms, or that the threshold for symptomatic presentation varies among individuals. The overall statistically significant difference in the distribution of osseous changes between Group A and Group B ($p=0.002$) provides robust evidence supporting a direct association between bruxism and structural alterations in the TMJ, irrespective of immediate symptomatic presentation. Side wise analysis of condylar osseous changes indicated that flattening was marginally more common in the left condyle (26.7%) compared to the right (20.0%). This finding is consistent with earlier reports by Kumar et al. [6] and Casazza et al. [7], which also noted higher frequencies of flattening on the left side. However, some studies, such as that by Virlan et al. [8], have reported conflicting results, with a higher prevalence of flattening in the right condyle, suggesting potential geographical or population-specific variations in TMJ loading patterns or adaptive responses. Sclerosis was proportionally more frequent in males (41.3%) and also slightly more prevalent in the right condyle (30.0%) in our study, aligning with certain previous investigations [9]. In contrast, other studies by Shetty et al. [10] found no statistically significant gender differences in sclerosis, highlighting variability attributable to diverse study methodologies or demographic characteristics. Osteophyte formation exhibited higher prevalence in the left condyle (6.7%), consistent with findings from Gomes et al. [11] and Vemareddy et al. [12]. However, Lobbezoo et al. [13] reported no statistically significant side differences for osteophytes. Surface erosion was also more frequent in the left condyle (5.0%), which broadly aligns with literature associating erosive changes with inflammatory cytokines and chronic microtrauma. Nevertheless, Wang et al. [14,15] reported no such significant lateral association for erosion. The highly significant side wise difference observed in our study ($p=0.001$) strongly implies a preferential loading pattern or a differential biomechanical response between the left and right TMJs in individuals with bruxism within our study population. While significant associations were observed between specific surface shape changes and clinical symptoms in TMD patients, which is consistent with prior studies linking morphological alterations to functional impairment, it is important to acknowledge that such correlations are not universal. Serafim et al. [16] noted that radiographic changes do not always correlate perfectly with symptomatic presentation, highlighting that gross radiographic findings may not always translate directly into clinical pain or dysfunction. This underscores the multifactorial nature of pain perception and the adaptive capacity of biological systems. Finally, gender-based comparisons within our study showed no statistically significant differences in the overall prevalence of specific osseous changes ($p=0.06$). This finding aligns with several contemporary studies by, Hu et al. [17], which also reported similar patterns. Conversely, Sahidi et al. [18] have reported contradictory findings, suggesting that gender may exert an influence on specific types of TMJ pathology or that the interaction between gender and TMJ health is population-dependent. In conclusion, this study reaffirms the invaluable utility of CBCT as a highly accurate diagnostic tool for assessing subtle and overt osseous changes in the TMJ condyle in both symptomatic and asymptomatic bruxism patients. Its capacity to provide high quality, three-dimensional images with minimized radiation exposure positions it as an effective modality for comprehensive TMJ pathology evaluation. The findings from this investigation contribute significantly to the evolving body of evidence supporting the integration of CBCT into routine clinical practice, particularly for the precise diagnosis and subsequent management of bruxism related TMJ disorders. This study represents one of the few conducted within the specific North Indian population to systematically utilize CBCT for assessing TMJ pathology in bruxism patients. The employment of CBCT, a relatively low radiation imaging modality compared to conventional CT, is a notable strength. The findings contribute significantly to the growing body of evidence supporting CBCT's efficacy in accurately diagnosing subtle and overt TMJ changes in bruxism patients. Such data are crucial for informing policymakers and researchers in the development of region specific clinical guidelines and effective therapeutic strategies. The judicious use of CBCT in this study further underscores its potential as a reliable and increasingly accessible diagnostic tool, particularly relevant in regions where advanced imaging technologies may have limited availability or higher associated costs. Despite its strengths, this study is subject to several limitations that warrant consideration for future research. Firstly, its conduction at a single diagnostic center in North India inherently limits the broad generalizability of the findings to more diverse global populations or other regional demographics. A larger sample size and the inclusion of multiple centers would substantially enhance the study's external validity and applicability. Secondly, several important confounding factors that could influence TMJ morphology and symptomatology were not comprehensively considered. These include specific occlusal load characteristics, individual patient habits (e.g., unilateral mastication, clenching force intensity), and undiagnosed or subclinical systemic conditions. For instance, patients with systemic inflammatory or metabolic conditions like rheumatoid arthritis, un-diagnosed osteoarthritis, or osteoporosis may present with distinct patterns of osseous changes that are not solely attributable to bruxism. Furthermore, while the non-instrumental diagnostic approach for bruxism is practical and widely used, it possesses inherent limitations concerning objectivity and precision when compared to more definitive instrumental measures such as polysomnography or surface electromyography.

Future investigations should endeavor to address these limitations by incorporating a more diverse patient population, considering a broader range of clinical and systemic variables, and ideally, utilizing multi-center, prospective designs for generating more robust and generalizable results.

## Conclusion

This study demonstrates that bruxism is associated with significant condylar osseous alterations that are detectable with CBCT imaging, regardless of whether a patient is symptomatic or asymptomatic. While flattening and sclerosis were more prevalent in symptomatic cases, the presence of osteophytes and erosion in the asymptomatic group suggests that these changes may represent early, pre-symptomatic adaptive responses. The use of CBCT serves as a valuable diagnostic tool for the early detection and comprehensive assessment of these crucial TMJ morphological changes. Early identification allows for timely intervention in bruxism patients, which is critical for preventing the progressive deterioration of the TMJ and improving patient outcomes and quality of life.

## Conflict of Interest

The authors have no conflicts of interest regarding this investigation.

## References


1. Valesan, L.F., Da-Cas, C.D., Réus, J.C., Denardin, A.C.S., Garanhani, R.R., Bonotto, D., Januzzi, E. and de Souza, B.D.M. (2021): Prevalence of temporomandibular joint disorders: a systematic review and meta-analysis. Clinical Oral Investigations 25, 441-453.
2. McNeely, M.L., Armijo Olivo, S. and Magee, D.J. (2006): A systematic review of the effectiveness of physical therapy interventions for temporomandibular disorders. Physical Therapy 86, 710-725.
3. Qamar, Z., Alghamdi, A.M.S., Haydarah, N.K.B., et al. (2023): Impact of temporomandibular disorders on oral health related quality of life: a systematic review and meta-analysis. Journal of Oral Rehabilitation 50, 706-714.
4. Schiffman, E., Ohrbach, R., et al. (2014): Diagnostic criteria for temporomandibular disorders (DC/TMD): clinical and research applications. Journal of Oral Facial Pain and Headache 28, 6-27.
5. Tesch, R.D., Calcia, T.B. and de Nordenflycht, D. (2024):

Unveiling MRI based structural phenotypes in temporomandibular joint osteoarthritis: implications for clinical practice and research. Dental Press Journal of Orthodontics 29, e24spe4.

6. Kumar, S., K., C.L. and Aniyan, Y. (2022): Assessment of condylar osseous changes in patients with bruxism using cone beam computed tomography a cross sectional observational study. Journal of Positive School Psychology 6, 3.
7. Casazza, E., Ballester, B., Siaud, B. et al. (2023): Relationship between bruxism and mandibular bone modifications based on medical imaging: a scoping review. BMC Oral Health 23, 483.
8. Vîrlan, M.J.R., Nimigean, V., Păun, D.L., Bisoc, A. and Nimigean, V.R. (2024): Modifications of the articular eminence inclination in association with the loss of occlusal support in the molar area. A cone-beam computed tomography study. Romanian Journal of Morphology and Embryology 65, 297-307.
9. Vasegh, Z., Safi, Y., Azar, M.S., Ghazizadeh Ahsaie, M. and Arianezhad, S.M. (2023): Assessment of bony changes in temporomandibular joint in patients using cone beam computed tomography a cross-sectional study. Head & Face Medicine 19,47.
10. Shetty, S., Satish Babu, C.L., Surendra Kumar, G.P. and Deepthi, B.C. (2010): Bruxism: a literature review. Journal of Indian Prosthodontic Society 10, 141-148.
11. Gomes, L.R., Gomes, M.R., Jung, B., Paniagua, B., Ruellas, A.C., Gonçalves, J.R., Styner, M.A., Wolford, L.M. and Cevidanes, L. (2015): Diagnostic index of three-dimensional osteoarthritic changes in temporomandibular joint condylar morphology. Journal of Medical Imaging 2, 034501.
12. Vemareddy, S., Kannan, A., Raghuram, P. and Kannan, N. (2019): Assessment of morphological changes of articular eminence and condyle using CBCT. International Journal of Maxillofacial Imaging 5, 58-62.
13. Lobbezoo, F., Ahlberg, J., Glaros, A.G., Kato, T., Koyano, K., Lavigne, G.J., de Leeuw, R. and Svensson, P. (2013): Bruxism defined and graded: an international consensus. Journal of Oral Rehabilitation 40, 2-4.
14. Wang, M.Q., Zhang, J.H., Cai, X.Y. and Ma, X.C. (2012): Magnetic resonance imaging assessment of temporomandibular joint anterior disc displacement and condylar erosion in patients with TMJ arthralgia. Journal of Oral Rehabilitation 39, 741-748.
15. Wang, M.Q., Zhang, J.H., Cai, X.Y. and Ma, X.C. (2021): A logistic analysis prediction model of TMJ condylar erosion in patients with TMJ arthralgia. BMC Oral Health 21, 687.
16. Serafim, A.P., Silva, P.L.P., de Almeida, E.O., de Oliveira, A.S. and Grossmann, E. (2014): Correlation between clinical signs and symptoms of temporomandibular dysfunction and radiographic findings. Cranio 32, 13-18.
17. Hu, X., Sujanamulk, B., Lakshmi, C.R. and Li, C. (2024): Age and gender related morphometric assessment and degenerative changes of temporomandibular joint in symptomatic subjects and controls using cone beam computed tomography (CBCT): a comparative analysis. Current Medical Imaging 20, 1-12.
18. Shahidi, S., Salehi, P., Abedi, P., Dehbozorgi, M., Hamedani, S. and Berahman, N. (2018): Comparison of the bony changes of TMJ in patients with and without TMD complaints using CBCT. Journal of Dentistry (Shiraz University of Medical Sciences) 19, 85-92.

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# Digital Smile Design: A Comprehensive Narrative Review in Contemporary Prosthodontics

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## Abstract

Digital Smile Design (DSD) represents a paradigm shift in esthetic and functional planning within prosthodontics. It integrates facial, dental, and gingival parameters into a single digital workflow that enhances diagnostic accuracy, interdisciplinary communication, and patient engagement. This narrative review summarizes the conceptual evolution, clinical workflow, software platforms, recent evidence, and future directions of DSD. Literature from 2010–2025 was analyzed, emphasizing studies from 2020 onward that evaluated clinical effectiveness, patient satisfaction, and technological innovation. The review highlights how DSD bridges digital technology with esthetic philosophy, providing clinicians with predictable and patient centered outcomes. Future developments such as artificial intelligence (AI), augmented and virtual reality (AR/VR), and 4D dynamic analysis are expected to refine treatment predictability and personalization further.

## Keywords

Digital Smile Design; Prosthodontics; Esthetic Dentistry; CAD/CAM; Visagism; 4D Smile Design; Artificial Intelligence

## Introduction

Esthetic dentistry has evolved from an art guided by subjective perception to a discipline supported by measurable facial and dental parameters. In prosthodontics, where rehabilitation of form and function must harmonize with the patient's identity, the visualization of the final outcome before treatment begins has become a defining clinical advantage.

Traditional diagnostic wax-ups and photographic mock-ups were often limited by 2D static representation and inter-operator variability. With advances in imaging, digital photography, and CAD/ CAM systems, clinicians can now simulate, analyze, and communicate esthetic outcomes virtually. Among the most influential innovations is Digital Smile Design (DSD) a concept introduced by Christian Coachman and Marcelo Calamita that enables clinicians to analyze the smile dynamically, plan esthetics based on facial proportions, and transfer designs precisely into clinical reality.

DSD has transformed not only prosthodontic rehabilitation but also patient communication. By visualizing the proposed outcome before any irreversible procedure, patients become co-authors in their treatment journey. The approach promotes interdisciplinary synergy between prosthodontists, periodontists, orthodontists, and technicians, ensuring that both esthetic and functional goals are met.

Recent literature between 2020 and 2025 emphasizes DSD's impact on patient satisfaction, communication efficiency, and clinical predictability. However, despite growing popularity, its integration into everyday prosthodontic practice requires understanding its workflow, evidence base, limitations, and technological variations areas this review aims to address.

## Methodology

This article follows the format of a narrative literature review rather than a systematic review. Sources were identified through electronic searches of PubMed, Scopus, Google Scholar, and Web of Science for

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studies published between 2010 and 2025 using the keywords: Digital Smile Design, DSD workflow, esthetic prosthodontics, CAD/CAM planning, and visagism.

Priority was given to peer reviewed articles in prosthodontic and esthetic journals (e.g., J Prosthodont Res, Int J Esthet Dent, J Clin Exp Dent, J Prosthodont). Both clinical trials and descriptive studies were included to ensure comprehensive coverage. Grey literature, conference proceedings, and non-peer reviewed blogs were excluded.

Each article was reviewed for content describing DSD's workflow, software tools, clinical applications, outcomes, and innovations. Emphasis was placed on findings published from 2020 onward to highlight the most contemporary perspectives. The final synthesis integrates evidence, clinical relevance, and expert opinion to provide a coherent understanding of DSD's role in modern prosthodontics.

## Evolution of Digital Smile Design

The concept of Digital Smile Design (DSD) emerged from the need to connect esthetic principles with digital technology for reproducible, predictable, and patient centric outcomes. Originally, smile analysis and design were based on manual photographic tracing and diagnostic wax-ups. These analog methods were highly dependent on operator skill and lacked objective calibration.

Christian Coachman introduced DSD in the early 2000s as a digital communication and planning protocol that combined dental and facial analysis using calibrated digital photographs. Over time, DSD evolved from a 2D visual planning tool to a multidimensional platform integrating intraoral scans, 3D facial scans, and CAD/CAM manufacturing.

## Generational Development of DSD

| Generation | Era | Key Features | Limitations |
|---|---|---|---|
| 1st Generation | Early 2000s | Manual drawings on printed photographs; simple facial-dental proportion tracing. | Low reproducibility; subjective. |
| 2nd Generation | 2008–2012 | 2D digital drawings using PowerPoint/Keynote; calibration with digital rulers. | Static image-based; no depth information. |
| 3rd Generation | 2013–2016 | Integration with CAD/CAM and 3D model scanning. | Limited facial motion capture. |
| 4th Generation | 2017–2021 | Full digital workflows using intraoral and facial scans; 3D printing mock-ups. | Requires advanced hardware/software. |
| 5th Generation (4D DSD) | 2022–Present | Incorporates facial motion, emotion analysis, and AI-driven automation. | High cost; need for validation and training. |

The transition from static to dynamic digital workflows has allowed prosthodontists to design restorations that not only fit functionally but also complement facial movement and emotional expression.

Recent studies (e.g., Alharkan et al., 2024; Cureus Systematic Review 2024) have confirmed that DSD significantly improves interdisciplinary planning and patient communication, reducing treatment time and enhancing esthetic predictability.

## Core Principles of Smile Design

The DSD philosophy merges objective measurement with subjective perception. A successful design aligns the dental framework with the patient's facial morphology and personality.

### Facial Analysis

- Establishes horizontal and vertical reference lines: interpupillary line, facial midline, and commissural line.
- Ensures the dental midline coincides with or parallels the facial midline.
- Facial thirds and fifths are evaluated to maintain proportion and symmetry.

### Dental Analysis

- Evaluates tooth dimensions, incisal edge position, and smile arc curvature.
- Adheres to esthetic principles such as the Golden Proportion or the Recurring Esthetic Dental (RED) proportion.
- Considers buccal corridor, gingival zenith, and emergence profile.

### Gingival and Phonetic Considerations

- The zenith of each anterior tooth should follow a gentle curvature parallel to the lower lip.
- Gingival margins should be symmetrical and respect the biological width.
- Phonetics are analyzed to determine incisal edge position and labial inclination.

## Visagism and Emotional Harmony

Visagism personalizes smile design by reflecting the patient's character traits in tooth form and arrangement energetic, delicate, bold, or calm. DSD integrates visagism into digital workflows, providing individualized esthetic outcomes and improving patient satisfaction.

## Digital Workflow of Digital Smile Design

The DSD workflow translates esthetic vision into a systematic digital pathway from diagnosis to definitive restoration.

Figure 1 illustrates this sequential protocol.

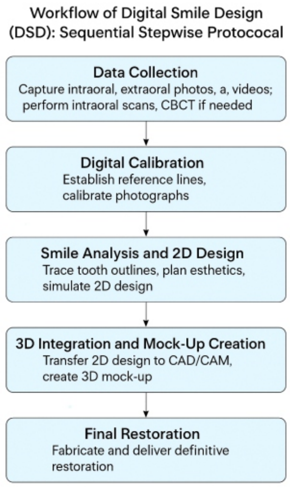


**Figure 1. Workflow of Digital Smile Design (DSD): Sequential Stepwise Protocol**

## Step by Step Protocol

1. Data Collection High resolution intraoral and extraoral photographs are captured in standardized poses frontal, lateral, and smiling views along with short videos to record dynamic facial movements. Intraoral scans and CBCT (if required) provide digital impressions and 3D anatomical data.
2. Digital Calibration Reference lines are established using facial landmarks such as the interpupillary line, facial midline, and commissural plane. Digital rulers calibrate the photographs to real world proportions, ensuring accurate scaling between 2D images and 3D models.
3. Smile Analysis and 2D Design Software tools are used to trace tooth outlines, define incisal curvature, and visualize ideal tooth proportions. Esthetic corrections are simulated virtually to assess harmony with lips and facial features.
4. 3D Integration and Mock-Up Creation The approved 2D design is transferred to CAD/CAM software or DSD-specific applications such as DSD App, 3Shape Smile Design, or Exocad Smile Creator. Virtual wax-ups are generated and converted into physical mock-ups through 3D printing or milling.
5. Clinical Validation The mock-up is tried intraorally to evaluate esthetics, phonetics, and occlusion. Patient feedback is gathered, allowing modifications before final restoration. Studies report higher case acceptance following this phase.
6. Final Restoration The validated design guides definitive restoration fabrication. CAD/CAM ceramic or composite restorations are produced and delivered, ensuring the digital design translates accurately to clinical reality.

## Clinical Significance

The DSD workflow enhances predictability, patient communication, and interdisciplinary collaboration. By integrating facially driven analysis with precise digital manufacturing, prosthodontists can minimize chair-side adjustments, improve esthetic outcomes, and reduce patient anxiety.

## Software Platforms for Digital Smile Design

Digital Smile Design is supported by several software platforms that allow clinicians to analyze, simulate, and execute esthetic planning with precision. The choice of software depends on the clinical need, available technology, and the level of integration required between facial scans, intraoral scans, and CAD/CAM systems.

Modern DSD platforms provide 3D visualization, facial mapping, and real time modification tools that link digital planning to laboratory workflows. Some systems even allow cloud collaboration between clinicians and technicians, enabling simultaneous design input.

| Software | Key Features | Clinical Application |
|---|---|---|
| DSDApp® (Coachman Clinic) | Combines 2D/3D facial analysis, video recording, and AI-based mock-ups; compatible with iPad workflows. | Comprehensive smile rehabilitation and multidisciplinary planning. |
| 3Shape Smile Design | Cloud-based real-time simulation; integrates with intraoral and facial scans; automatic tooth alignment. | Chairside esthetic consultations and quick case acceptance. |
| PlanmecaRomexis® Smile Design | Integrates with Planmeca scanners and imaging; supports facial overlays. | Esthetic smile design linked with 3D imaging and prosthetic workflows. |
| Exocad Smile Creator | Full CAD/CAM integration; 3D virtual articulation; exports for milling or 3D printing. | Complex implant-supported and full-mouth restorative cases. |
| Smile Designer Pro | Stand-alone software using photographs; ideal for quick 2D visualization and presentations. | Preliminary planning, patient education, and esthetic previews. |
| Adobe Photoshop / Keynote | Manual calibration and tracing on 2D images; cost-effective but skill-dependent. | Academic use and basic esthetic teaching tool. |

Table 1. Commonly Used Digital Smile Design Software

These software solutions enhance accuracy, visualization, and efficiency. Their integration with intraoral scanners and CAD/CAM fabrication enables complete digital workflows from planning to delivery.

## 2D vs 3D Digital Smile Design

The progression from 2D to 3D DSD represents a key leap in prosthodontic esthetic planning. While 2D analysis serves as the foundation, 3D workflows offer improved spatial understanding, depth perception, and clinical precision.

**Comparison of 2D vs 3D Digital Smile Design**

| Parameter | 2D Digital Smile Design | 3D Digital Smile Design |
|---|---|---|
| Data Source | Digital photographs | Intraoral & facial 3D scans |
| Analysis Type | Static – based on calibrated images | Dynamic – based on volumetric data |
| Accuracy | Limited by 2D depth perception | High spatial accuracy with 3D mapping |
| Output | Visual design for presentation | CAD/CAM-ready model for fabrication |
| Time & Cost | Faster, lower cost | Higher cost, longer setup time |
| Clinical Suitability | Basic smile evaluation | Complex restorative & implant planning |

Figure 2. Comparison of 2D vs 3D Digital Smile Design

**Clinical Relevance:** 2D DSD remains valuable for patient motivation and preliminary planning. However, 3D DSD provides clinically transferable data for prosthesis fabrication, improving occlusal accuracy and esthetic predictability. The combination of both (hybrid 2D-3D workflow) is now considered best practice in advanced prosthodontics.

## Clinical Applications in Prosthodontics

Digital Smile Design plays a crucial role in various prosthodontic disciplines, from single tooth restorations to full arch rehabilitation.

**1. Anterior Esthetic Restorations**

In veneers, crowns, and laminate restorations, DSD helps define optimal tooth length, width, and incisal curvature. Mock-ups allow patients to visualize outcomes before tooth preparation, increasing confidence and acceptance.

**2. Full Mouth Rehabilitation**

By combining occlusal and esthetic analysis, DSD provides a digital blueprint for complex rehabilitations. 3D mock-ups ensure functional harmony and symmetry across both arches.

**3. Implant Prosthodontics**

Integration with CBCT and guided surgery software enables implant planning based on final prosthetic contours. This "prosthetically driven" approach enhances emergence profile design and esthetic integration of implants.

**4. Interdisciplinary Treatment Planning**

DSD promotes communication among orthodontists, periodontists, and maxillofacial surgeons. Shared virtual planning enhances precision in soft tissue management and orthodontic alignment.

**5. Post Radiotherapy Rehabilitation**

In patients with altered facial esthetics due to radiation therapy or maxillofacial defects, DSD aids in visualizing symmetry and designing obturators or facial prostheses that restore both form and confidence.

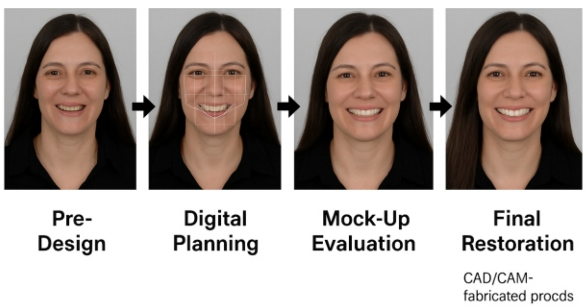


Figure 3. Case Example Flow in DSD-Guided Treatment

**Description**

This figure illustrates a clinical case sequence using the DSD protocol:

1. Pre-Design - Initial photographic and digital records.
2. Digital Planning-2D and 3D simulation for esthetic analysis.
3. Mock-Up Evaluation - Intraoral verification of function and esthetics.
4. Final Restoration - CAD/CAM fabricated prosthesis replicating the approved digital plan.

**Clinical Insight:** Chairside implementation of digital mock-ups not only shortens the diagnostic phase but also facilitates patient participation and interdisciplinary coordination. Studies (e.g., Rigo et al., 2023) have shown a significant reduction in adjustment time and improved patient satisfaction following DSD based rehabilitation.

## Recent Evidence on Digital Smile Design (2020–2025)

The recent decade has seen a surge in research evaluating Digital Smile Design (DSD) for its clinical accuracy, patient satisfaction, and interdisciplinary relevance. Between 2020 and 2025, studies have shifted focus from descriptive feasibility toward measurable clinical outcomes, integrating DSD with artificial intelligence (AI), augmented reality (AR), and motion analysis technologies.

**Key themes in contemporary literature include**

- Enhanced esthetic predictability through CAD/CAM integration.
- Patient centered communication and improved case acceptance.
- Quantitative evaluation of smile harmony using 3D and dynamic facial scanning.
- Development of AI-driven tools for automated design and proportion analysis.

| Author & Year | Journal | Study Design | Key Findings | Clinical Relevance |
|---|---|---|---|---|
| **Coachman et al., 2020** | *Int J Esthet Dent* | Narrative Review | Defined updated DSD workflow integrating 3D scanning and video analysis. | Established standardized DSD workflow for clinical communication. |
| **Gonçalves et al., 2021** | *J Prosthodont Res* | Comparative Study | Compared 2D vs 3D DSD accuracy; 3D designs showed superior spatial correlation. | Advocated 3D DSD for complex esthetic cases. |
| **Meereis et al., 2022** | *J Clin Exp Dent* | Prospective Study | Evaluated patient satisfaction before and after DSD mock-up. | Found >90% improvement in esthetic perception and satisfaction. |
| **Rigo et al., 2023** | *J Prosthet Dent* | Clinical Trial | Compared DSD-assisted vs conventional wax-up planning. | Reported 35% reduction in adjustment time for DSD group. |
| **Alharkan et al., 2024** | *Cureus* | Systematic Review | Reviewed 36 studies; confirmed DSD improves communication and treatment predictability. | Reinforced DSD's value in evidence-based prosthodontics. |
| **Thapa et al., 2024** | *Int J Esthet Dent* | Cross-sectional Study | Analyzed AI-assisted smile design software accuracy. | AI improved design time and reduced manual error. |
| **Zhang et al., 2025** | *J Prosthodont Res* | Experimental Study | Integrated AR visualization with DSD workflow. | Enabled real-time facial simulation for enhanced treatment planning. |

Table 2. Summary of Key Studies on DSD (2020–2025)

**Synthesis:** Recent evidence emphasizes DSD's transition from a visualization tool to a data driven planning system. Its integration with AI and AR technologies offers objective analysis, reducing subjectivity in smile design. However, the literature also highlights the need for operator calibration and standardization of digital protocols.

## Advantages and Limitations of DSD

**Advantages**

- Enhanced Esthetic Predictability: DSD ensures that smile proportions and harmony are based on objective measurements.
- Improved Communication: Shared digital files promote collaboration among clinicians, technicians, and patients.
- Patient Engagement: Visual simulation increases confidence

and treatment acceptance.

- Reduced Chair-Time Adjustments: Digital mock-ups minimize trial-and-error during final delivery.
- Interdisciplinary Synergy: Facilitates coordination between prosthodontic, orthodontic, and surgical disciplines.
- Digital Record Keeping: All stages are stored digitally, enabling follow-up comparisons and easy modification.

**Limitations**

- Learning Curve: Requires digital literacy and experience in software handling.
- Equipment Cost: High initial investment for scanners and software licenses.
- Data Integration Issues: Compatibility challenges between different software platforms.
- Subjectivity in Analysis: Despite digital tools, esthetic evaluation remains partly subjective.
- Ethical & Privacy Concerns: Patient images and data must be securely stored and managed.

Despite these limitations, consistent training and integration with AI-driven systems are gradually overcoming most technical and financial barriers.

## 4D Digital Smile Design and AI Integration

**Concept of 4D DSD**

The latest advancement in digital esthetics is 4D Digital Smile Design (DSD), which adds the dimension of time and motion to traditional 3D planning. This approach considers facial expressions, phonetics, and emotional responses while designing the smile.

4D DSD uses motion capture videos, dynamic facial scans, and AI algorithms to map how the lips, cheeks, and teeth move during speech and smiling. This ensures restorations appear natural in all dynamic facial expressions rather than just static photos.

**Clinical Workflow of 4D DSD**

1. Dynamic Data Capture - Short 3D videos of smiling and speaking are recorded using digital scanners or smartphones with depth sensors.
2. AI Motion Mapping - The software analyzes lip mobility, muscle symmetry, and incisal display during motion.
3. Design Integration - Tooth morphology and position are adjusted based on natural movement trajectories.
4. Virtual Reality Preview - AR/VR tools allow patients to experience their designed smile dynamically.

**Fabrication -** The final motion-calibrated design is milled or printed, ensuring harmony during speech and expression.

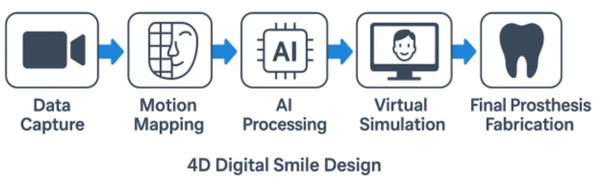


Figure 4. 4D Digital Smile Design – Integration of Dynamic Facial Motion

**Description**

Figure 4 illustrates the integration of 4D Digital Smile Design into prosthodontic workflow. The figure demon-strates how dynamic facial scans and AI mapping inform tooth positioning to maintain esthetic balance during natural movement.

(This figure will depict: data capture, motion mapping, AI processing, virtual simulation, final prosthesis fabrication.)

## Clinical Impact of AI and 4D Integration

- Personalized Treatment: AI analyzes patient specific features, suggesting tooth shapes that match facial personality traits (visagism based prediction).
- Efficiency: Automated tooth setup reduces manual planning time by up to 50%.
- Precision: AI-based calibration ensures reproducible reference line placement.
- Predictive Simulation: 4D rendering provides a real-life digital twin for prosthodontic verification.

Recent studies (Zhang et al., 2025; Thapa et al., 2024) demonstrate that AI-assisted DSD reduces design errors and enhances esthetic predictability by integrating both static and dynamic analyses.

## Future Directions in Digital Smile Design

Digital Smile Design (DSD) continues to evolve as a multidisciplinary ecosystem rather than a single software or protocol. The integration of artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) will define the next era of prosthodontic esthetics.

## Emerging trends shaping the future of DSD include

**1. Artificial Intelligence and Machine Learning**

AI will enable automated facial and dental landmark detection, instant smile analysis, and intelligent prosthetic design suggestions. Machine learning algorithms trained on thousands of smiles will provide statistically optimized tooth forms, proportions, and color mapping for individualized treatment.

**2. 4D Digital Twins**

The concept of a "digital twin" a complete dynamic virtual replica of the patient will allow real time simulation of mastication, phonetics, and emotional expression. This advancement bridges digital planning and functional biomechanics.

**3. Integration with AR/VR for Patient Communication**

Augmented and virtual reality systems are now allowing patients to "wear" their new smile virtually. This immersive visualization improves acceptance and emotional connection to treatment outcomes.

**4. Cloud Based Collaborative Design**

Interdisciplinary cloud platforms will connect prosthodontists, dental technicians, and specialists across continents, facilitating synchronous design review, case planning, and laboratory production.

5. **Predictive Analytics in Smile Esthetics**

Predictive models will assess treatment outcomes before intervention by simulating occlusal forces, gingival adaptation, and esthetic perception metrics, improving long-term prognosis and satisfaction.

6. **Accessibility and Education**

Open source software and mobile based applications are expected to democratize DSD, allowing its inclusion in undergraduate and postgraduate dental education worldwide.

Together, these advancements will push prosthodontics toward a fully digital, patient centered, and functionally dynamic practice model.

**Comparison Between DSD and Conventional Esthetic Planning**

The following table summarizes how DSD differs fundamentally from traditional analogesthetic planning, emphasizing digital precision, communication efficiency, and patient centered outcomes.

| Parameter | Conventional Esthetic Planning | Digital Smile Design (DSD) |
|---|---|---|
| Approach | Manual, based on static photographs and wax-ups. | Digital, dynamic, and data-driven workflow integrating 2D and 3D scans. |
| Accuracy | Operator-dependent and subjective. | Objective, standardized through digital calibration. |
| Visualization | 2D mock-ups and diagnostic wax-ups. | Real-time digital simulation in 3D or 4D motion. |
| Patient Involvement | Limited, reliant on dentist explanations. | High — patients visualize and approve outcomes before treatment. |
| Interdisciplinary Communication | Sequential and paper-based. | Cloud-based collaboration in real time. |
| Time Efficiency | Time-consuming with multiple physical models. | Faster turnaround with integrated CAD/CAM workflows. |
| Cost | Lower initial investment. | Higher initial cost but greater long-term efficiency. |
| Documentation | Physical models and photos. | Comprehensive digital record, easy to store and share. |

**Table 3. Comparison Between Digital Smile Design (DSD) and Conventional Esthetic Planning**

**Clinical Note:** The digital approach enhances consistency, communication, and accuracy, making it ideal for esthetic-driven prosthodontics. However, clinicians must balance technological dependence with clinical judgment and artistry.

## Conclusion

Digital Smile Design (DSD) has transformed prosthodontic practice from an art guided by perception to a science grounded in measurable digital data. By linking facial analysis, esthetic principles, and CAD/CAM technology, DSD enables clinicians to plan, simulate, and execute restorations with unparalleled precision.

Recent developments, including AI integration and 4D motion analysis, have elevated DSD from a diagnostic tool to a dynamic clinical ecosystem. It not only enhances esthetic predictability but also strengthens patient confidence, interdisciplinary coordination, and educational potential.

Nevertheless, successful implementation requires digital literacy, ethical data management, and a commitment to esthetic excellence. As DSD continues to evolve, it will remain central to modern prosthodontic rehabilitation where technology, artistry, and human emotion converge into a truly digital smile.

## References (Vancouver Style, 2020 – 2025)

1. Coachman C, Calamita M, Sesma N. Digital Smile Design: A conceptual framework for modern esthetic dentistry. Int J Esthet Dent. 2020;15(2):158–178.
2. Gonçalves A, de Araujo FM, Prado M. Comparative analysis between 2D and 3D Digital Smile Design workflows. J Prosthodont Res. 2021;65(4):482–490.
3. Meereis CT, de Almeida AJ, Brondani LP. Patient satisfaction following Digital Smile Design assisted treatment. J Clin Exp Dent. 2022;14 (3): e217–e224.
4. Rigo L, Basso A, Souza M, et al. Clinical outcomes of prosthodontic rehabilitation using DSD versus conventional wax-up techniques. J Prosthet Dent. 2023; 130 (2): 221–229.
5. Alharkan R, Alrashoudi F, Alotaibi N. Digital Smile Design: Systematic review of clinical applications. Cureus. 2024; 16 (1): e48562.
6. Thapa P, Ghimire S, Adhikari S. Artificial intelligence assisted smile design: Accuracy and efficiency assessment. Int J Esthet Dent. 2024;18 (1): 33–44.
7. Zhang Y, Lin H, Xu J. Integration of augmented reality into Digital Smile Design: A new paradigm for real-time planning. J Prosthodont Res. 2025; 69 (2):145–152.
8. Coachman C, Pinho A, Sesma N. DSDApp integration for virtual interdisciplinary planning. Int J Esthet Dent. 2023; 17 (4): 302–312.
9. Lin WS, Morton D. Digital communication in esthetic prosthodontics: The DSD approach. J Prosthet Dent. 2021; 125 (3): 380–388.
10. Paravina R, et al. Advances in digital smile evaluation and tooth color prediction. J EsthetRestor Dent. 2024; 36 (1): 25–36.
11. Sharma A, Jain N. 4D Digital Smile Design: Dynamic evaluation of esthetics and function. Dent J. 2025; 13 (3): 172–180.
12. Moura S, Gonçalves T. Emotional impact of AI-based smile previews on patient satisfaction. J Prosthodont. 2024; 33 (5): 485–493.
13. Ramesh K, Gupta V. Cloud-based DSD collaboration in prosthodontics. J Clin Exp Dent. 2023;15(8): e746–e752.
14. Lee SJ, Park J. Predictive modeling of facial dynamics using machine learning. J Prosthet Dent. 2025;133 (4): 563– 570.

15. Bhatia N, Patel S. Limitations and ethical concerns in digital smile workflows. J Dent Educ. 2023; 87 (6): 715–724.
16. Kim Y, Han J. CAD/CAM workflow validation in DSD-based ceramic restorations. J Adv Prosthodont. 2022; 14 (4): 297–306.
17. Calvani C, Saponaro G. Integration of DSD into full mouth rehabilitation: A case series. J EsthetRestor Dent. 2024; 36 (5): 455–467.
18. Silva E, Costa T. The influence of DSD on interdisciplinary planning. Eur J ProsthodontRestor Dent. 2021; 29 (4): 182–189.
19. Fernandes M, Oliveira D. AI-based tooth morphology prediction in DSD software. J Dent Tech. 2025; 12 (2): 83–91.
20. Diniz A, Rocha M. Clinical validation of 4D smile analysis in prosthodontic rehabilitation. J Prosthodont Res. 2025; 69 (3): 299–312.

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# Orthodontics Meets Nanotech: The Future of Dental Precision

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## Abstract

Nanotechnology, the science of working at the scale of atoms and molecules, is reshaping the way dentistry and orthodontics are practiced. Once considered futuristic, it is now offering practical solutions to everyday clinical challenges. In orthodontics, nanotech has moved beyond theory into real-world applications: wires and brackets coated with nanoparticles reduce friction and bacterial buildup, adhesives strengthened with nano-composites improve bonding, and smart nano-sensors embedded in brackets allow orthodontists to monitor forces in real time. These innovations make treatments faster, more comfortable, and more predictable for patients.

By combining materials science, biotechnology, and digital diagnostics, nanotechnology is transforming orthodontics from a mechanical process into a biologically intelligent and digitally guided specialty. The result is a new era of precision, safety, and patient centered care where braces and aligners are not just tools for moving teeth, but part of a smarter, more responsive system designed to protect oral health while delivering better outcomes.

## Introduction

The word "nano" comes from the Greek word for "dwarf." The science of modifying matter, expressed in billionths of meters or nanometers, roughly the size of two or three atoms, is known as nanotechnology. Its action at a scale of one billionth of a meter, or one ten thousandth of the width of a human hair, is what primarily sets it apart. To put it simply, it's atomic or molecular engineering.

The branch of science known as nanotechnology studies the manipulation of matter at the nanoscale. The field of nanotechnology is expanding daily and has shown great promise in all areas of medicine, including dentistry.

## History

The term “nanometer” was first introduced by Richard Zsigmondy, who received the Nobel Prize in Chemistry in 1925. Later, in 1959, the foundations of nanotechnology were laid by American physicist and Nobel laureate Richard Feynman, who is credited with presenting the idea and vision for this revolutionary field.[11]

Feynman's introduction of this new research area sparked wide scientific interest, leading to the development of two distinct approaches that outline the various possibilities for synthesizing nanostructures. These manufacturing approaches fall under two categories: top-down and bottom-up, which differ in degrees of quality, speed and cost.[9] The “top-down” approach is nothing but the utilization of miniaturization techniques to construct micro/nanoscale structures from a macroscopic material or a group of materials by utilizing machining and etching techniques. The best example of a “top-down” approach is the photolithography technique used in the semiconductor industry to fabricate components of an integrated circuit by etching micro/nanoscale patterns on a silicon wafer.

The “bottom-up” approach refers to the construction of macromolecular structures from atoms or molecules that have the ability to self-organize or self-assemble to form a macroscopic structure.[6]

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## Nanodentistry

Various applications of Nanoparticles (NPs) are used in the field of dentistry. Their chemical and physical properties are based on the metals or the compounds used to prepare the NPs.[9]

| Field | Application | Details |
|---|---|---|
| Dental Diagnostics | Nano-biosensing | Biosensors combine a biologically active element with a transducer to generate measurable signals. Enhances diagnostic accuracy.[5] |
| Preventive Dentistry | Nano-toothbrush | Nanogold or nanosilver colloids are incorporated between bristles. These show antibacterial effects and improve plaque removal, potentially reducing periodontal disease (Raval et al., 2016).[9] |
| Prosthodontics | 1. $TiO_2$ nanoparticles in PMMA 2. Nano-ceramic CAD/CAM blocks | 1. 0.4% $TiO_2$ added to 3D printed PMMA improves antibacterial and mechanical properties. 2. Lava Ultimate blocks (3M ESPE) offer superior aesthetics, durability, and fracture resistance.[5] |
| Endodontics | Antibacterial nanoparticles in composites/adhesives | Nanoparticles (ZnO, Ag, polyethylenimine) inhibit bacteria by: • Disrupting membranes • Inhibiting sugar metabolism & enzymes • Generating ROS • Preventing DNA replication. Nanocoatings resist saliva and adhesion. Size-dependent effectiveness.[3] |
| Implantology | Nanostructured surface coatings on implants | Improves bone integration. Types: • **Nanostructured diamond** – High hardness, toughness, low friction, good titanium adhesion • **Hydroxyapatite coatings** – Enhance osteoblast activity • **Metallo-ceramic coatings** – Gradual transition from metal to ceramic improves strength and integration[2] |
| Orthodontics | 1. Nano-coated wires & brackets<br>2. Enamel remineralizing agents & nano-composites<br>3. Nano-sensors for force measurement | 1. Improve wear resistance, reduce friction, and provide antibacterial action.<br>2. Help in enamel repair and reduce demineralization around brackets.<br>3. Enable real-time force monitoring for efficient treatment.[4] |

Table No. 1 : Clinical Applications of Nanomaterials in Dentistry

## Nanotecnology In Orthodontics

The application of nanotechnology in orthodontics has made the treatment procedures, efficient, fast, reliable, safe, and relatively less painful.

The recent commercial developments include:

i. Nano Coated Orthodontic Wires & Brackets,
ii. Nano Composites,
iii. Nano Sensor for Force Measurement.[4]

### I. Nano Coated Orthodontic Wires

Orthodontic archwires are used to generate mechanical forces that are transmitted through brackets to bring about tooth movement in the correction of a malocclusion. They are also used for retentive purposes, i.e., to maintain teeth in their current position. Orthodontic arch wires are fabricated from base metal alloys such as stainless steel, Ni-Ti, and beta-titanium alloys as well as from esthetic materials.[7] To perform the dental movement the orthodontic appliance must exert sufficient force to counteract and surpass this resistance.

` It has been measured that more than 60% of the orthodontic force applied to obtain dental movement is expected to be lost due to frictional forces (Kusy and Whitley 1997).[9]

### II. Nano Composites

Composite materials have been primarily used in orthodontics as adhesive agents for securing orthodontic brackets and bands to the surface of the teeth. The largest application of nanoparticles has been in dental composite materials. Although mechanical strength showed improvement, polishability remained a drawback. At that time, the maximum filler content achieved ranged between 70-77 wt.%. Micro-filled composites, with particle sizes in the range of 10–100 nm, were found unsuitable for use in high stress bearing regions of the dentition, such as Class I, II, and IV restorations. Furthermore, the particle dimensions of these hybrid composites did not correspond to the natural sizes of hydroxyapatite crystals, dentinal tubules, or enamel rods. There was also a potential for compromise in adhesion between the macroscopic restorative material and the nanoscopic (110 nm in size) tooth structure.[6]

### III. Nano Coated Orthodontic Brackets

Orthodontic brackets bonded to teeth provide the means to transfer force from the activated archwire to the teeth to facilitate tooth movement. Orthodontic brackets can be metallic [stainless steel (SS), titanium (Ti), or gold] or tooth-colored (plastic or ceramic). The surface characteristics [roughness and surface free energy (SFE)] of the brackets play a significant role in reducing friction and plaque (bio film) formation. While newly bonded brackets initially present with smooth surfaces, their surface roughness and surface free energy (SFE) can undergo changes throughout the course of orthodontic treatment. A nanoindenter coupled with an atomic force microscope (AFM) has been traditionally used to evaluate nanoscale surface characteristics of biomaterials.[6]

### IV. Nano Sensor for Force Measurement

To ensure teeth are moved efficiently while avoiding harmful side effects such as external apical root resorption (EARR), orthodontic treatment requires the application of carefully controlled forces and moments. Since each patient's biological tolerance varies, researchers have been working on developing smart brackets that integrate three dimensional mechanical sensors within their bases. These sensors allow for real time monitoring of forces and moments acting on the teeth, making treatment more precise and individualized.[7]

**Lapatki & Paul (2007)**

Conducted experiments with a full-scale smart bracket design that incorporated a stress sensor chip, demonstrating the feasibility of measuring orthodontic forces directly at the bracket level.[4]

**M. Kuhlet al (2013)**

Designed a prototype bracket equipped with a wireless stress - mapping chip. Its notable features included:

- Stress resolution of 11 kPa
- Low power consumption of 1.75 mW
- Fabrication using a 0.35 μm CMOS process
- Integration of a micro coil micro coil created through gold electroplating in a photoresist mask[7]

## Conclusion

Nanotechnology, defined as the manipulation of matter at the atomic and molecular scale, has rapidly expanded into dentistry and orthodontics, offering novel solutions to long-standing clinical challenges. Its applications span diagnostics, preventive care, prosthodontics, endodontics, implantology, and orthodontics, with nanoparticles and nanostructured materials enhancing antibacterial activity, mechanical strength, and biocompatibility. In orthodontics specifically, innovations such as nano-coated wires and brackets reduce frictional resistance and bacterial colonization, while nano-composites improve adhesive properties and restorative performance. These developments collectively contribute to more efficient, reliable, and patient friendly treatment protocols.

Recent advances also include the integration of smart nano-sensors into orthodontic brackets, enabling real time monitoring of applied forces and moments to optimize tooth movement and minimize risks such as external apical root resorption. By bridging materials science, biotechnology, and digital diagnostics, nanotechnology is transforming orthodontics from a purely mechanical discipline into a biologically intelligent and digitally guided specialty. This convergence promises a future of enhanced precision, safety, and predictability in orthodontic care, establishing nanotechnology as a cornerstone of next-generation dental practice.

## References


1. Kovvuru SK, Mahita VN, Manjunatha BS, Babu BS. Nanotechnology: The emerging science in dentistry. Journal of Orofacial Research. 2012; 2 (1): 33-6.
2. Baheti MJ, Toshniwal NG. Nanotechnology: a boon to dentistry. J Dent Sci Oral Rehabil. 2014; 5: 78-88.
3. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. International journal of nanomedicine. 2015 Oct 8: 6371-94.
4. Umalkar DG, Jawale BA, Patil S. Application of nanotechnology in orthodontics: A critical review. IJCO. 2017; 1: 9-12.
5. AlKahtani RN. The implications and applications of nanotechnology in dentistry: A review. The Saudi dental journal. 2018 Apr 1; 30 (2):107-16.
6. Subramani K, Subbiah U, Huja S. Nanotechnology in orthodontics -1: The past, present, and a perspective of the future. InNanobiomaterials in clinical dentistry 2019 Jan 1 (pp. 279-298). Elsevier.
7. VJoy N, Gupta P, Jyothikiran H, Raghunath N. Nanotechnology in Orthodontics-An Update. Nanotechnology. 2020 Sep;7(9).
8. De Stefani A, Bruno G, Preo G, Gracco A. Application of nanotechnology in orthodontic materials: a state-of-the-art review. Dentistry journal. 2020 Nov 9;8(4):126.
9. Ahmed MA. *Nanotechnology* in Orthodontics (Doctoral dissertation, University of Baghdad).
10. Sreenivasalu PK, Dora CP, Swami R, Jasthi VC, Shiroorkar PN, Nagaraja S, Asdaq SM, Anwer MK. Nanomaterials in dentistry: current applications and future scope. Nanomaterials. 2022 May 14;12 (10):1676.
11. Roy P, Roy P. Current Trends of Nanotechnology in Orthodontics. Cureus. 2024 Sep 9;16 (9).

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# Post Orthodontic Stability: Role of Retainer type and Duration

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## Abstract

**Aim:** To evaluate post-orthodontic stability in relation to retainer type and duration of wear, and to assess whether combined retention offers advantages over single retainer protocols.[1]

**Materials and Methods:** The study was carried out at the Department of Orthodontics, Subharti Dental College, Meerut. A cross-sectional questionnaire based survey was conducted using a structured Google Form. A total of 94 completed responses were analyzed descriptively using percentage distribution.

**Results:** Most respondents were aged 18–25 years (90.4%) male and female (68.1%). Dental students comprised of the largest group (66%), followed by orthodontic patients (13.8%) and general dentists (9.6%). Among participants, 41.5% had undergone orthodontic treatment, predominantly with metal braces (45.7%). Treatment duration was typically less than two years. Retainer compliance was poor: although 21.3% reported fixed retainers and 18.1% clear thermoplastic retainers, 38.3% never wore one and only 18.1% used retainers daily. Advice on retention duration varied, with most instructed to wear retainers for less than two years, while lifelong retention was rarely recommended (6.4%). Post-treatment outcomes showed that 31.9% experienced significant tooth shifting, while satisfaction with dental alignment was mixed (57.4% satisfied, 33% neutral). Retainer-related problems were common, particularly discomfort (26.6%) and breakage (14.9%). Clinicians reported oral hygiene issues (39.1%) and poor compliance (21.7%) as major challenges.

**Discussion:** This survey underscores that post-orthodontic relapse remains a common clinical concern, with many respondents reporting noticeable tooth movement after treatment. Poor retainer compliance emerged as a key factor, as only a minority wore retainers daily despite awareness of their importance. Even among dental students, adherence was suboptimal, suggesting that knowledge alone does not ensure compliance and highlighting the need for sustained motivation and follow-up. Communication gaps were evident, with several respondents unsure of their retainer type, while clear thermoplastic retainers, though esthetically preferred, were frequently associated with discomfort and breakage. Oral hygiene issues were the most frequent challenge with fixed retainers, reflecting their known association with plaque accumulation and periodontal complications.

The wide variation in advised retention duration illustrates the absence of standardized guidelines, with few patients instructed on prolonged or lifelong retention despite growing evidence supporting extended use. Moderate satisfaction with dental alignment further suggests that even minor post treatment changes can affect patient perception of success. Overall, these findings emphasize the importance of clear retention protocols, improved patient education, and individualized long-term planning to optimize orthodontic stability and patient satisfaction.

**Conclusion:** This study highlights poor long-term compliance with retainer use and variability in retention advice, contributing to post-treatment instability. Greater emphasis on patient education, standardized retention protocols, and strategies to improve adherence are essential to optimize orthodontic outcomes.

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## Introduction

Orthodontics aims to correct irregular bites and provide functional dental alignment[2]. Orthodontic treatment seeks to establish an optimal occlusal relationship that ensures functional harmony among the dentition, temporomandibular joint, and neuromuscular system[3]. Ensuring long-term stability of orthodontic outcomes remains a fundamental objective in clinical practice. The application of fixed or removable retention devices plays a critical role in minimizing post-treatment relapse[4].

Post orthodontic retention is considered one of the most debated topics in orthodontics. This stage of treatment focuses on keeping teeth in their new, corrected positions once active movement has finished. While retention is necessary for nearly every patient, there is little consensus on the best

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method to use for each case. If retention is not carried out, teeth often drift back toward their original alignment. Retention can be carried out using either removable or fixed retainers. There is no universally agreed length of time for retention, but research shows that the fibres around teeth need at least about 232 days to adapt to their new positions. Even after this period, teeth may still shift back over time. Because of this risk of relapse, many orthodontists choose to keep retainers in place for extended periods, and in some cases, indefinitely[5].Therefore effective retention planning is critical in long-term orthodontic care.

## Materials and Methods

The study was conducted in the Orthodontics Department of orthodontics and dentofacial orthopaedics at Subharti Dental College and Hospital, Meerut, and used questionnaires to explore how different retainers and the duration of time they are worn affecting the stability of orthodontic results. Participants included were orthodontically treated patients who had completed active treatment and were currently wearing retainers or had previously completed the retention phase.

## Study Population and Sample Size

A total of 94 completed responses were included in the final analysis. The majority of respondents belonged to the 18–25-year age group, and the study population comprised dental students, orthodontic patients, general dentists, and other respondents, providing a broad overview of retention related perceptions.

**Inclusion Criteria**

- Individuals who completed fixed orthodontic treatment.
- Age range between 18to35 years
- Patients willing to participate and able to provide informed consent.

**Exclusion Criteria**

- Patients undergoing active orthodontic treatment.
- Individuals with syndromic conditions or craniofacial anomalies affecting occlusion or stability.
- Unwilling or non-consenting participants.

**Survey Instrument**

Data was collected using a structured questionnaire created using Google Forms. The questionnaire consisted of closed ended and multiple choice items covering:

- Demographic information
- History of orthodontic treatment
- Type of retainer prescribed
- Duration of retention
- Daily compliance (for removable retainers)
- Patient-reported stability, relapse, or shifting
- Satisfaction and challenges related to retainer use

## Ethical Considerations

Participation in the study was voluntary, and informed consent was obtained electronically prior to questionnaire submission. Participant anonymity and confidentiality were strictly maintained throughout the study.

## Statistical Analysis

The collected data were entered into a spreadsheet and analyzed using descriptive statistical methods. Results were expressed as frequencies and percentage distributions. The findings were presented using tables and graphical representations, including pie charts, to facilitate clear interpretation of the data.

## Results

**Study design and sample characteristics**

This cross-sectional questionnaire based survey was conducted in accordance with the Materials and Methods described earlier. A total of 94 completed responses were included for analysis. Data were collected using a structured Google Form and analysed descriptively using percentage distribution.

Most respondents belonged to the 18–25year age group (90.4%), reflecting a young study population. Females constituted 68.1% of respondents, males constituted 30.9%, and a very small proportion preferred not to disclose gender. Regarding respondent profile, dental students formed the largest group (66%), followed by orthodontic patients (13.8%) and general dentists (9.6%).

| Variable | Category | Percentage |
|---|---|---|
| Age | <18 years | 4.3 |
| | 18-25 years | 90.4 |
| | 26-35 years | 5.3 |
| Gender | Male | 30.9 |
| | Female | 68.1 |
| | Prefer not to say | 1.0 |
| Respondent type | Dental Student | 66.0 |
| | Orthodontic Patient | 13.8 |
| | General Dentists | 9.6 |
| | Others | 10.6 |

Table 1. Demographic characteristics of respondents (n = 94)

## Orthodontic Treatment details

Among all respondents, 41.5% had undergone orthodontic treatment, while 58.5% had not orthodontic treatment. Among treated individuals, metal braces were the most commonly used appliance (45.7%), followed by self-ligating appliances (13.8%), ceramic braces (6.4%), and clear aligners (8.5%).

Treatment duration was reported as less than one year by 50%, 1–2 years by 34%, 2–3 years by 13.8%, and more than three years by a small minority 2.2%.

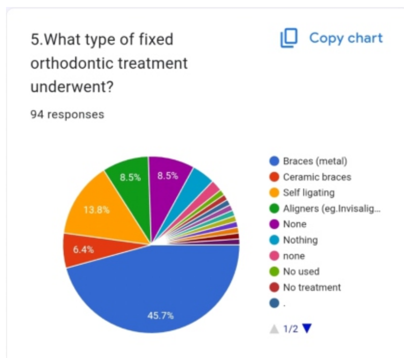


Figure 1. Distribution of type of orthodontic appliance used Pie chart depicting the proportion of metal braces, ceramic braces, self-ligating appliances, clear aligners and other response.

## Retainer type and Compliance

Regarding retention, 21.3% reported wearing fixed/bonded retainers, while 10.6% used Hawley retainers, 18.1% clear thermoplastic retainers, and 42.6% were unsure of the retainer type.

Only 18.1% of respondents wore their retainer daily, whereas

10.6% wore it occasionally. A considerable proportion (33%) stopped wearing retainers after the prescribed period, and 38.3% reported never wearing a retainer, indicating poor long-term compliance.

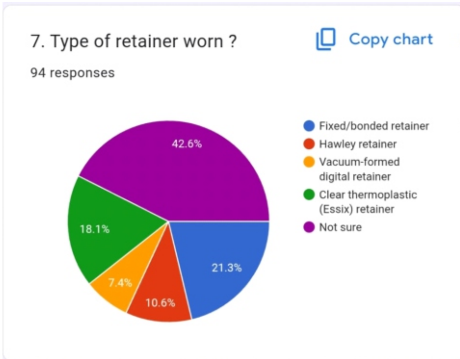


**Figure 2. Type of retainer worn by respondents Pie chart showing distribution of fixed, removable and uncertain retainer types.**

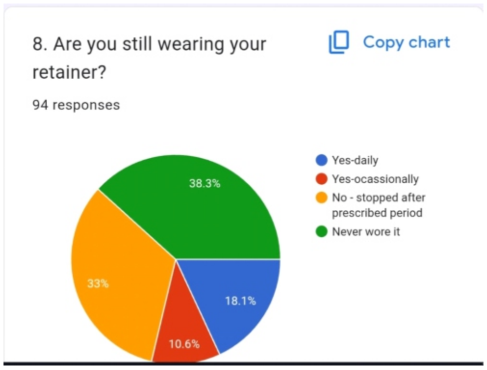


**Figure 3. Current retainer wearing status Pie chart illustrating daily, occasional, discontinued and non-users of retainers.**

## Duration advised for retention

Advice regarding retention duration varied considerably. 24.5% were advised less than 6 months, 23.4% for 6 months–1 year, 27.7% for 1–2 years, and only 6.4% were advised lifelong retention.


**Figure 4. Duration for which retainer wear was advised.**

## Post-treatment stability and satisfaction

When asked about post-treatment tooth movement, 31.9% reported significant shifting, 25.5% slight shifting, while 11.7% noticed no change and 30.9% were unsure.

Satisfaction with current dental alignment showed mixed responses. 23.4% strongly agreed and 34% agreed that they were satisfied, 33% remained neutral, while a smaller proportion expressed dissatisfaction.

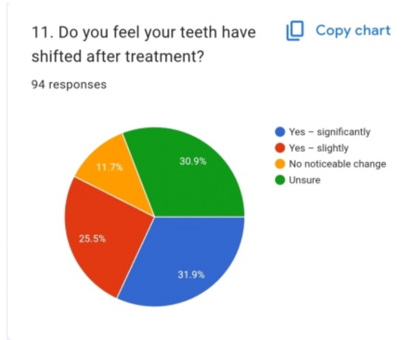


**Figure 5. Perceived tooth movement after orthodontic treatment.**

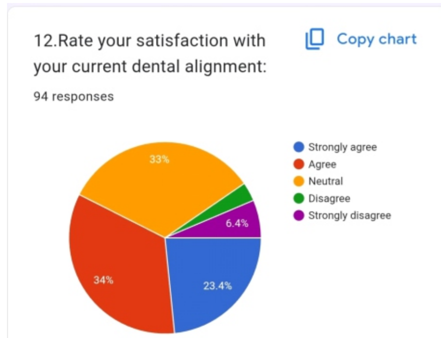


**Figure 6. Satisfaction with current dental alignment**

## Retainer related problems and clinical challenges

More than half of the respondents experienced retainer-related problems. Discomfort (26.6%) was the most common issue, followed by breakage (14.9%), poor fit (7.4%), and staining (6.4%).

From the clinician perspective, the most frequently observed challenges were oral hygiene issues (39.1%), poor compliance (21.7%), retainer loss (13%), and relapse despite retention (12%).

| Issue | Percentage |
|---|---|
| Oral Hygiene Issues | 39.1 |
| Poor Compliance | 21.7 |
| Retainer Loss | 13.0 |
| Relapse Despite Retention | 12.0 |
| Breakage | 8.7 |

**Table 2. Common retainer-related problems and challenges**

## Discussion

The present cross-sectional questionnaire based survey evaluated awareness, practices, and experiences related to orthodontic retention among a predominantly young population, with the majority of respondents belonging to the 18–25-year age group. The findings revealed considerable variability in retainer type usage, duration of retention advised, and patient compliance. A large proportion of participants were uncertain about the type of retainer provided after orthodontic treatment, and long-term compliance was notably poor, with many respondents discontinuing retainer use after the prescribed period or never wearing a retainer at all. Advice regarding retention duration was inconsistent, with most respondents being instructed to wear retainers for short-term periods and only a small proportion advised lifelong retention. A significant number of respondents reported post-treatment tooth movement ranging from slight to marked shifting, accompanied by moderate levels of satisfaction with current dental alignment. Retainer related issues such as discomfort, breakage, and poor fit were commonly experienced, while clinicians identified oral hygiene problems, poor compliance, retainer loss, and relapse despite retention as frequent challenges. These findings reflect existing gaps in patient awareness and adherence to retention protocols, which may adversely affect long-term orthodontic stability.

Retention has long been recognized as an essential phase of orthodontic treatment, as post-treatment changes may occur long after appliance removal. A Cochrane systematic review by Littlewood et al. highlighted that relapse is common and that retention is critical for maintaining treatment outcomes[1]. This supports the occurrence of post-treatment tooth movement reported by participants in the present study. Kartal and Kaya further emphasized that post-orthodontic changes are inevitable and that retainers play a crucial role in preserving alignment, favouring long-term retention strategies[2]. However, despite this strong evidence, the present study demonstrated limited compliance and short retention durations advised, reflecting an unfavourable deviation from established recommendations.

Pattanaik et al. reported that effective retention protocols significantly influence the stability of orthodontic outcomes, reinforcing the need for sustained retainer use[3]. Bonadio et al. also noted that long-term stability depends not only on orthodontic mechanics but also on post-treatment management strategies. In contrast, the present study revealed inconsistent retention advice and poor patient adherence, which may explain the high prevalence of perceived relapse.

The absence of universally accepted retention protocols has been widely reported. Knaup et al. demonstrated that even with fixed retainers, additional removable retainers may be required to improve stability, suggesting that retention strategies should be individualized. Similarly, Littlewood et al. reported insufficient high-quality evidence to support a single ideal retention approach. These findings may explain the wide variation in retention duration advised to participants in the present study, although such variability may negatively influence long-term stability.

Fixed retainers are widely advocated for maintaining post-treatment alignment, particularly in the mandibular anterior region. Bearn highlighted that bonded retainers eliminate patient compliance issues and are therefore advantageous for long-term stability. Renkema et al. reported a strong preference for fixed retainers among orthodontists to ensure mandibular anterior alignment. Pratt et al. similarly observed increasing global adoption of bonded retainers in orthodontic practice.

Despite these favourable findings, the present study showed that only a limited proportion of respondents reported wearing fixed retainers, while many were unsure of the retainer type provided, indicating a gap between clinician preference reported in the literature and patient reported experience.

Long-term clinical studies have demonstrated favourable outcomes with canine-to-canine bonded retainers. Zachrisson reported reliable long-term stability with directly bonded retainers[1]. Renkema et al. further confirmed the effectiveness of canine to canine bonded retainers in maintaining mandibular anterior alignment over extended periods[11].

Regarding material selection, Zachrisson emphasized that multistranded stainless-steel wires permit physiological tooth movement while reducing stress on bonded teeth[12]. Årtun reported acceptable periodontal responses associated with long-term use of such retainers when oral hygiene is maintained[13]. Dahl also supported their durability and clinical reliability[1]. In contrast, the present study identified oral hygiene challenges and retainer breakage as common problems, suggesting that the benefits of fixed retainers may be compromised without adequate maintenance and follow-up.

Evidence strongly supports prolonged or lifelong retention. Little et al. demonstrated progressive mandibular anterior crowding even 10–20 years after treatment completion, irrespective of initial treatment success[1]. Keim et al. reported a growing trend toward indefinite retention in contemporary orthodontic practice[1]. These findings contrast with the present study, where most respondents were advised of short-term retention, an unfavourable practice that may contribute to the high prevalence of post-treatment tooth movement reported. Despite their advantages, fixed retainers are associated with complications. Iliadi et al. reported that retainer failures are common, particularly within the first year[1]. Lee identified the adhesive enamel interface as the most frequent site of failure[1]. Kučera and Marek described unexpected complications, including unwanted tooth movement, emphasizing the importance of regular monitoring[1]. These findings are consistent with the present study, where breakage and relapse despite retention were commonly reported.

Aesthetic alternatives such as fiber-reinforced retainers have shown less favourable outcomes. Tacken et al. reported higher failure rates compared with multistranded wire retainers[2]. Bolla et al. observed increased debonding with long-term use of glass fiber reinforced retainers[21]. Chinvipas et al. further highlighted the risk of enamel fracture associated with repeated rebonding procedures[22]. These findings support continued preference for conventional multistranded wire retainers despite aesthetic limitations.

Periodontal health remains a key concern in long-term retention. Pandis et al. reported increased plaque accumulation around bonded retainers[23]. Conversely, Levin et al. emphasized that periodontal changes are largely influenced by oral hygiene rather than retainer presence alone[2]. Booth et al. concluded that permanently bonded retainers do not significantly compromise periodontal health when patients are adequately motivated and regularly followed up[2]. These findings suggest that periodontal risks can be minimized through appropriate patient education and maintenance.

The findings of the present study, when interpreted alongside existing literature, highlight the need for improved patient education regarding the importance of retention, retainer type, and duration of wear. Clinicians should emphasize long-term or lifelong retention, particularly in the mandibular anterior region, and ensure that patients are adequately informed about retainer maintenance and potential complications. Regular follow-up visits are essential to detect early failures, manage oral hygiene challenges, and prevent unintended tooth movement.

## Conclusion

Within the limitations of this questionnaire-based survey, the following conclusions can be drawn:

1. Post-orthodontic relapse or perceived tooth movement is common following active treatment.
2. Long-term retainer compliance is suboptimal, even among individuals with dental education.
3. Discomfort, appliance breakage, and oral hygiene difficulties are major factors affecting continued retainer use.
4. Considerable variation exists in the type and duration of retention protocols advised by clinicians.
5. Individualized, case dependent retention strategies, supported by patient education and regular follow-up, are essential for improving post-orthodontic stability.

Further longitudinal studies with extended follow-up periods are recommended to better assess the long-term effectiveness of different retainer types and retention durations.

## References


1. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Retention procedures for stabilising tooth position after treatment with orthodontic braces. Cochrane Database of Systematic Reviews. 2016 (1).
2. Pattanaik S, Veeraraghavan VP, Dasari AK, Aileni KR, Patil SR. Orthodontic Retention Protocols: Evaluating the Effectiveness of Different Retention Protocols in Maintaining Post-Treatment Tooth Alignment. Pesquisa Brasileira em Odontopediatria e Clínica Integrada. 2024 Dec 20; 25: e230199.
3. Bonadio MF, Cotrin P, Marín Ramirez CM, Fialho T, da Silva Moura W, de Oliveira RC, de Oliveira RC, Valarelli FP, Pinzan-Vercelino CR, Salvatore Freitas KM. The Influence of Occlusal Adjustment on Long-term Post-treatment Stability of Orthodontic Treatment. The Open Dentistry Journal. 2023 Oct 12; 17 (1).
4. Knaup I, Schulte U, Bartz JR, Niederau C, Craveiro RB, Jäger A, Wolf M. Post-treatment stability in orthodontic retention with twistflex retainers do patients benefit from additional removable retainers?. Clinical oral investigations. 2022 Aug; 26 (8): 5215-22.
5. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Orthodontic retention: a systematic review. Journal of orthodontics. 2006 Sep; 33 (3): 205-12.
6. Kartal Y, Kaya B. Fixed orthodontic retainers: a review. Turkish journal of orthodontics. 2019 Jun 1; 32 (2): 110.
7. Bearn DR. Bonded orthodontic retainers: a review. American Journal of Orthodontics and Dentofacial Orthopedics. 1995 Aug 1; 108 (2): 207-13.
8. Renkema AM, Hélène Sips ET, Bronkhorst E, Kuijpers-Jagtman AM. A survey on orthodontic retention procedures in The Netherlands. The European Journal of Orthodontics. 2009 Aug 1;31(4):432-7.
9. Pratt MC, Kluemper GT, Hartsfield Jr JK, Fardo D, Nash DA. Evaluation of retention protocols among members of the American Association of Orthodontists in the United States. American Journal of Orthodontics and Dentofacial Orthopedics. 2011 Oct 1; 140 (4): 520-6.
10. Zachrisson BU. Clinical experience with direct bonded orthodontic retainers. American journal of orthodontics. 1977 Apr 1; 71 (4): 440-8.
11. Renkema AM, Renkema A, Bronkhorst E, Katsaros C. Long-term effectiveness of canine to canine bonded flexible spiral wire lingual retainers. American Journal of Orthodontics and Dentofacial Orthopedics. 2011 May 1;139 (5): 614-21.
12. Zachrisson BU. Multistranded wire bonded retainers: from start to success. American Journal of Orthodontics and Dentofacial Orthopedics. 2015 Nov 1;148 (5): 724-7.
13. Årtun J. Caries and periodontal reactions associated with long-term use of different types of bonded lingual retainers. American Journal of Orthodontics. 1984 Aug 1; 86 (2):112-8.
14. Dahl EH. Longterm experience with direct bonded lingual retainers. J. Clin. Orthod.. 1991;25:619-30.
15. Little RM, Riedel RA, Artun J. An evaluation of changes in mandibular anterior alignment from 10 to 20 years postretention. American Journal of Orthodontics and Dentofacial Orthopedics. 1988 May 1; 93 (5): 423-8.
16. Keim RG, GOTTLIEB EL, NELSON AH, VOGELS III DS. 2002 JCO Study of Orthodontic Diagnosis and Treatment Procedures. Age (years). 2002;1996:1990.
17. Iliadi A, Kloukos D, Gkantidis N, Katsaros C, Pandis N. Failure of fixed orthodontic retainers: a systematic review. Journal of dentistry. 2015 Aug 1; 43 (8): 876-96.
18. Lee RT. The lower incisor bonded retainer in clinical practice: a three year study. British journal of orthodontics. 1981 Jan; 8 (1): 15-8.
19. Kučera J, Marek I. Unexpected complications associated with mandibular fixed retainers: a retrospective study. American Journal of Orthodontics and Dentofacial Orthopedics. 2016 Feb 1; 149 (2): 202-11.
20. Tacken MP, Cosyn J, De Wilde P, Aerts J, Govaerts E, Vannet BV. Glass fibre reinforced versus multistranded bonded orthodontic retainers: a 2 year prospective multi-centre study. The European Journal of Orthodontics. 2010 Apr 1; 32 (2):117-23.
21. Bolla E, Cozzani M, Doldo T, Fontana M. Failure evaluation after a 6-year retention period: a comparison between glass fiber-reinforced (GFR) and multistranded bonded retainers. International orthodontics. 2012 Mar 1;10 (1):16-28.
22. Chinvipas N, Hasegawa Y, Terada K. Repeated bonding of fixed retainer increases the risk of enamel fracture. Odontology. 2014 Jan; 102 (1): 89-97.
23. Pandis N, Vlahopoulos K, Madianos P, Eliades T. Long-term periodontal status of patients with mandibular lingual fixed retention. The European Journal of Orthodontics. 2007 Oct 1; 29 (5): 471-6.
24. Levin L, Samorodnitzky Naveh GR, Machtei EE. The association of orthodontic treatment and fixed retainers with gingival health. Journal of periodontology. 2008 Nov; 79 (11): 2087-92.
25. Booth FA, Edelman JM, Proffit WR. Twenty-year follow-up of patients with permanently bonded mandibular canine to canine retainers. American Journal of Orthodontics and Dentofacial Orthopedics. 2008 Jan 1;133(1):70-6.

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# A Review: Diagnostic and Therapeutic Advances including Oral Health Tuberculosis and HIV Co-Infection

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## Abstract

Tuberculosis (TB) and HIV co-infection remains a major global health challenge, with each infection worsening immune suppression and complicating diagnosis and treatment. Early detection and integrated care are essential, and oral health plays a pivotal role in this process. Oral manifestations are often early indicators of systemic disease progression in TB HIV patients. TB-related oral lesions such as ulcers, granulomas, and lymph adenopathy may appear even in the absence of pulmonary symptoms, while HIV-related conditions including candidiasis, hairy leukoplakia, periodontal diseases, xerostomia, and Kaposi's sarcoma are highly prevalent due to compromised immunity. Co-infection intensifies oral inflammation, impairs nutrition, affects speech and swallowing, and significantly reduces quality of life. Strengthening oral examinations, incorporating dental professionals into multi disciplinary teams, and improving access to diagnostic and preventive oral care can enhance early case identification, support treatment outcomes, and reduce morbidity among affected populations.

**Keywords :** Tuberculosis, HIV, coinfection, diagnostics, LAM, Xpert, tNGS, preventive therapy, rifapentine, dolutegravir, Palms, MDR-TB, IRIS, vaccines

## Introduction

TB/HIV syndemics enhance rciprocal risk: TB speeds up the advancement of HIV disease, increasing death, while HIV increases the annual risk of TB disease by about 20 times (WHO 2020, Gupta 2021). Despite significant advance - ments since 2010, PLHIV still contribute significantly to TB fatalities (WHO 2024, Spotlight 2024). UNAIDS estimates ~39.9–40.8 million PLHIV and ~630,000 AIDS-related fatalities in 2023–2024, while WHO's Global TB Report 2024 projects ~10.8 million incident TB cases and ~1.25 million TB deaths in 2023, including ~161,000 among PLHIV (WHO 2024, UNAIDS 2025). Important populations and areas outside of sub-Saharan Africa are disproportionately impacted by ongoing gaps in diagnosis, timely treatment, and prevention. Due to its synergistic interaction, disproportionate burden in low and middle income countries, and ongoing contribution to morbidity and mortality, tuberculosis (TB) and HIV co-infection continue to rank among the most serious global health issues. The syndemic link between TB and HIV continues to impede efforts to manage both diseases, despite tremendous advancements in diagnosis, treatments, and public health initiatives. According to the World Health Organization (WHO), an estimated 10.8 million TB incidents HIV and Mycobacterium tuberculosis have a special two-way relation -ship. Co-infected people have a 20-30 times higher chance of developing active TB than people without HIV due to HIV-induced immunosuppression, which also significantly raises the risk of latent TB infection reactivation and speeds up the disease's progression to active state (Goletti 2025, UNAIDS 2024). On the other hand, active TB accelerates CD4 T-cell depletion, immuno logical activation, and viral replication, all of which worsen HIV pathogenesis (UNAIDS 2025). Atypical and smear-negative presentations are typical in severe immuno suppression, and the clinical spectrum resulting from this interaction ranges from asymptomatic infection to widespread, life-threatening disease (The Guardian, 2024).

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### Epidemiology of TB-HIV Co-Infection

Following difficulties brought on by the pandemic, TB notifications and treatment success rates increased in 2022–2023, and in 2023, TB fatalities decreased once more (WHO 2024, Spotlight 2024). While some regions (such as parts of Eastern Europe and Central Asia) are experiencing an increase in HIV incidence and inadequate TB prevention, other regions (such as Eastern and Southern Africa) are continuing to drive mortality reductions through ART scale-up and TB services integration (UNAIDS 2025, The Guardian 2024, HIV.gov 2025). Stigma, migration, incarceration, and social variables continue to be major obstacles to TB/HIV control.

### Pathophysiology and Clinical Spectrum

HIV-related CD4 depletion increases bacillaemia and extrapulmonary/disseminated TB by preventing granuloma formation [Dorman, S. 2018]. Immune status affects clinical phenotypes: smear-negative, non-cavitary, and disseminated illness (e.g., mycobacteria) is the result of progressive immunosuppression [Martinson, N. A., Hoffmann, C. J., & Chaisson, R. E. 2011]. Immunorestitution inflammatory syndrome (IRIS), which usually manifests within weeks of starting ART, is one way that ART alters risk; high mycobacterial burden and CD4 <50 cells/µL are associated with the highest risk (Meintjes, Müller).

### Advances in TB Screening and Triage in PLHIV

CRP and symptom screening. C-reactive protein (CRP) enhances triage performance and is suggested where accessible; WHO-recommended symptom screenings in PLHIV show a moderate sensitivity.

Focused screening. Given the high pre-test probability, individuals with advanced HIV illness, those without ART, and those with low CD4 counts should undergo aggressive screening (CXR/CAD, sputum NAATs, urine LAM) (Dorman.2018, Hoffmann,2011)

Guidelines for CAD and other digital tools for TB screening and care pathway optimization have been released by WHO.

### Diagnostic Innovations for TB in PLHIV

Assays for nucleic acid amplification (NAATs). Xpert MTB/RIF Ultra offers quick detection of rifampicin resistance and improves sensitivity over previous assays. Isoniazid and fluoroquinolone resistance can be detected closer to the point of care thanks to Truant and Xpert MTB/XDR extensions [Dorman, S. 2018, Nimma, S. K. 2025]. When accessible, these assays are advised as first-line testing in policy updates for 2023–2024.

LAM testing in urine. Lateral-flow urine LAM (AlereLAM) enhances same-day diagnosis and survival for PLHIV with CD4 =200 cells/µL (or who are critically unwell); the next-generation SILVAMP/FujiLAM exhibits more sensitivity and is advancing via policy channels [Dhana, A., Gupta 2023] With continuous assessments of FujiLAM implementation, WHO revised LAM guidelines to expand use in advanced HIV illness [Nimma, S. K. 2025, Stevens, L. 2025]

Sequencing of the next generation. In many contexts, targeted NGS (tNGS) and WGS for TB drug-resistance profiling are now advised or covered by policy guidelines, which reduces the need for sequential phenotypic testing and speeds up the time to an actionable regimen [Meya, D.2021].

New platforms and biomarkers. Although host transcrip - tional markers (such RISK11), IP-10, and CRISPR-based diagnostics show promise, they are not currently commonly used in PLHIV because of operational limitations and inconsistent immunosuppressive performance [Chakravorty, S. 2017].

Point-of-care ultrasonography and imaging. When combined with NAATs and LAM, low-resource ultrasound can identify disseminated TB in advanced HIV, such as pericardial effusion, ascites, or lymphadenopathy; this expedites the start of empirically supported yet evidence-based treatment [Huerga, H 2020].

### TB Preventive Treatment (TPT) in PLHIV

One Regimen. Short rifapentine-based regimens, such as 1HP (isoniazid + rifapentine daily for 1 month) and 3HP (weekly for 3 months), have greater completion rates and are not inferior to lengthier isoniazid monotherapy [Jin, W. 2025]. For PLHIV, WHO now provides several TPT alternatives, including 1HP, 3HP, 3HR, 4R, and context-specific 6–36H. IMPAACT4TB and other initiatives have increased implemen - tation [Mendelsohn, S. 2021].

Particular demographics. TPT is beneficial for children, adolescents, and pregnant/postpartum people; growing data (such DOLPHIN Moms) may increase the number of pregnancy alternatives based on rifapentine [Mendelsohn, S 2021].

Pearls of programmatic. Prior to TPT, check for active TB using symptoms, CXR/CAD, NAATs, and LAM if necessary. Control medication interactions with ART (integrase inhibitors and rifapentine need special attention). Track hepatotoxicity and provide adherence assistance (digital tools can be useful). [Chelkeba, L. 2020].

### Timing and Choice of ART During TB Treatment

The best time to begin ART. In order to balance IRIS risk against mortality, randomized trials (SAPiT, CAMELIA, and STRIDE) showed that ART initiated within 2 weeks after TB medication for CD4 counts <50 cells/µL and by 8 weeks for higher CD4 counts improved survival . Global norms incorporate this timing [H. J., & Kwon, Y. S. (2015].

### Drug-Drug Interactions with Rifamycin

Dolutegravir (DTG): Rifampicin lowers DTG exposure by inducing UGT1A1/CYP3A; 50 mg of DTG twice daily is advised during and for approximately two weeks following rifampicin (assuming INSTI resistance is not present) [A.Z., Kumar 2023]. Guidelines continue to recommend BID dosing until more policy changes are made, despite ongoing trials suggesting standard-dose DTG may be enough ins o m e situations.

Due to significant exposure decreases, rifampin should not be taken with bictegravir or long-acting cabotegravir/rilpivirine. In many individuals, efavirenz and rifampicin can still be used together at conventional dosages; however, because of its tolerability and resistance profile, DTG-based regimens are recommended when practical.

Mitigation of TB-IRIS. Early ART still improves net survival in high-risk patients (CD4 <50, disseminated TB); in some patients, a brief course of prednisone can lower the incidence of paradoxical TB-IRIS after starting ART.

### Treatment of Drug-Susceptible TB in PLHIV

Results and regimens. When adherence is encouraged and medication interactions are controlled, standard 6-month regimens continue to be successful in PLHIV [Mekonnen, Z. 2020]. Programmatic use in PLHIV is increasing, however the evidence is not as strong as it is in HIV-negative individuals. Four-month rifapentine-moxifloxacin regimens (TBTC Study 31) show promise but need cautious ART interaction monitoring.

Technologies for adherence. When DOTS is not feasible, digital adherence solutions (such as 99DOTS and smart pill boxes) can provide support and increase completion without coercion.

### Management of Drug-Resistant TB (DR-TB) in PLHIV

Brief, oral-only regimens. The treatment of MDR/RR-TB has been revolutionized by BPaLM (bedaquiline, pretomanid, linezolid, and moxifloxacin) and BPaL variations. WHO supports programmatic use of TB-PRACTECAL with consideration for safety and resistance surveillance, since it shown better results with a 6-month BPaLM regimen compared to lengthier SOC [D. J., Kenge, A. P., Maartens,2020]. Although linezolid-related toxicity necessitates close monitoring, HIV-positive participants benefited similarly when on effective ART.

Optimization with Linezolid. According to ZeNix, linezolid at lower doses and for shorter durations can still be effective with fewer side effects; cautious titration and TDM, when possible, are helpful, even in PLHIV.

Beyond Nix-TB. Earlier Nix-TB studies supported BPaL for XDR-TB; later projects have expanded eligibility with pharmacovigilance [Blumer, J. L.2017]

ART-related factors. Avoid strong inducers after rifampicin periods; when necessary, take into account other ART backbones; bedaquiline (CYP3A substrate) has complex interactions [R. R. 2009]

Severe TB with extrapulmonary in PLHIV. Advanced HIV increases the risk of developing TB meningitis, disseminated TB, and pericardial illness, all of which have significant fatality rates  Adjunctive corticosteroids and high-dose rifampicin methods have been shown to be effective in treating TB meningitis (with subtle HIV-specific effects) Urine LAM, blood cultures (if possible), and tissue NAAT/histology are frequently needed for early bacteriologic confirmation.

### Special Populations

Safety statistics for rifapentinebased TPT and TB treatment in pregnancy are changing; isoniazid preventive therapy (IPT) is still appropriate when benefits outweigh concerns; and during pregnancy and the postpartum period, prioritize mother survival with timely ART and TB medication.

Children and adolescents: Urine LAM can help with advanced pediatric HIV with severe sickness; pediatric DTG dosage should follow BID while rifampicin guidance; dispersible bedaquiline and DTG formulations offer better co-treatment choices

Key populations: Integrated TB/HIV, harm reduction, and social protection services are necessary for individuals with substance use disorders, migrants, and those who are incarcerated [LaCourse, S. M 2023]

### Care Models and Programmatic Integration

HIV-aligned differentiated service delivery (DSD) can co-deliver TPT with ART refills, diagnostics (including same-day NAAT + LAM), and TB screening. Multi-month dispensing, community-based follow-up, and decentralized, nurse-led approaches all increase completion and decrease pre-treatment loss to follow-up.

### Pipelines and Vaccines

Phase 3 trials are being conducted to ascertain the efficacy and durability of the M72/AS01E vaccine across populations, including PLHIV subsets, after it showed about 50% efficacy in a phase 2b trial among adults who were latently infected Although its function in high-risk adults and PLHIV is still unknown, BCG revaccination decreased persistent infection in teenagers in one trial [ Boyd, A. T. 2021] One important pillar for further bending incidence curves in environments with high HIV burdens is investment in TB vaccines.

### Future Paths

In areas where advanced HIV disease is prevalent, priorities include (i) scaling LAM and CAD; (ii) expanding 1HP/ 3HP with strong drug-interaction management; (iii) routine access to tNGS/WGS for quick DR-TB regimen design; (iv) adjusting DTG dosing with rifampicin as new information becomes available; (v) pharmacovigilance for BPaLM/BPaL in PLHIV; and (vi) accelerating M72 and other vaccine candidates.

### Practical, Step-by-Step Approach (Clinic Checklist)

TB symptoms, CRP (if available), CXR/CAD, sputum NAAT, and urine LAM if CD4 =200 or the patient is critically unwell at first contact.

If TB is suspected or confirmed, begin TB treatment right once; if CD4 is less than 50, begin ART within 2 weeks; if not, start ART within 8 weeks; and schedule DTG 50 mg BID with rifampicin (or efavirenz-based if DTG is not available). Steer clear of long-acting CAB/RPV and bictegravir whenu s i n g rifampicin.

Offer TPT (1HP/3HP preferable) if there is no active TB after ruling out active illness.

If DR-TB is suspected or confirmed, send tNGS/WGS, take BPaLM into account, keep an eye on linezolid toxicity, and make sure ART is compatible.

Adherence and safety: Make use of digital adherence tools; keep an eye out for TB-IRIS, QT effects (bedaquiline), and hepatotoxicity (prednisone should be considered in high-risk cases).

## References


1. Dorman, S. E., Schumacher, S. G., Alland, D., Nabeta, P., Armstrong, D. T., King, B., Hall, S. L., Chakravorty, S., Cirillo, D. M., Tukvadze, N., Bablishvili, N., Stevens, W., Scott, L., Rodrigues, C., Kazi, M. I., Joloba, M., Nakiyingi, L., Nicol, M. P., Ghebrekristos, Y., Anyango, I., … study team (2018). Xpert MTB/RIF Ultra for detection of Mycobacterium tuberculosis and rifampicin resistance: a prospective multi centre diagnostic accuracy study. The Lancet. Infectious diseases, 18(1), 76–84. https://doi.org/10.10 16/S1 473-3099(17)30691-6
2. Martinson, N. A., Hoffmann, C. J., & Chaisson, R. E. (2011). Epidemiology of tuberculosis and HIV: recent advances in understanding and responses. Proceedings of the American Thoracic Society, 8(3), 288–293. https:// doi.org/10.1513/pats.201010-064WR.
3. M K, S., Theja, K. P., Bhavani, K. G., Dara, C., Paloju, P., & Nimma, S. K. (2025). Clinical spectrum of tuberculosis among HIV infected patients in India: Correlation with immunological status using CD4 counts. Bioinform ation, 21(6), 1602–1605. https:// doi. org/10. 6026 /973206300211602.
4. Dhana, A., Gupta, R. K., Hamada, Y., Kengne, A. P., Kerkhoff, A. D., Yoon, C., Cattamanchi, A., Reeve, B. W. P., Theron, G., Ndlangalavu, G., Wood, R., Drain, P. K., Calderwood, C. J., Noursadeghi, M., Boyles, T., Meintjes, G., Maartens, G., & Barr, D. A. (2023). Clinical utility of WHO-recommended screening tools and development and validation of novel clinical prediction models for pulmonary tuberculosis screening among outpatients living with HIV: an individual participant data meta-analysis. European respiratory review : an official journal of the European Respiratory Society, 32(168), 230021. https:/ /doi.org/ 10.1183 /16000617.0021-2023.
5. Marquez, N., Carpio, E. J., Santiago, M. R., Calderon, J., Orillaza-Chi, R., Salanap, S. S., & Stevens, L. (2025). Performance of chest X-ray with computer-aided detection powered by deep learning-based artificial intelligence for tuberculosis presumptive identification during case finding in the Philippines. BMC global and public health, 3(1), 74. https://doi.org/10.1186/s44263-025-00198-y.
6. Meya, D. B., Tugume, L., Nabitaka, V., Namuwenge, P., Phiri, S., Oladele, R., Jibrin, B., Mobolaji-Bello, M., Kanyama, C., Maokola, W., Mfinanga, S., Katureebe, C., Amamilo, I., Ngwatu, B., Jarvis, J. N., Harrison, T. S., Shroufi, A., Rajasingham, R., Boulware, D., Govender, N. P., … Loyse, A. (2021). Establishing targets for advanced HIV disease: A call to action. Southern African journal of HIV medicine, 22(1), 1266. https:// doi.org /10.41 02 / sajhivmed.v22i1.1266.
7. Dorman, S. E., Schumacher, S. G., Alland, D., Nabeta, P., Armstrong, D. T., King, B., Hall, S. L., Chakravorty, S., Cirillo, D. M., Tukvadze, N., Bablishvili, N., Stevens, W., Scott, L., Rodrigues, C., Kazi, M. I., Joloba, M., Nakiyingi, L., Nicol, M. P., Ghebrekristos, Y., Anyango, I., … study team (2018). Xpert MTB/RIF Ultra for detection of Mycobacterium tuberculosis and rifampicin resistance: a prospective mult icentre diagnostic accuracy study. The Lancet. Infectious diseases, 18(1), 76–84. https:// doi.org/ 10.1016 /S147 3-3099(17)30691-6.
8. Huerga, H., Rucker, S. C. M., Bastard, M., Dimba, A., Kamba, C., Amoros, I., & Szumilin, E. (2020). Should Urine-LAM Tests Be Used in TB Symptomatic HIV-Positive Patients When No CD4 Count Is Available? A Prospective Observational Cohort Study From Malawi. Journal of acquired immune deficiency syndromes (1999), 83(1), 24–30.https://doi.org/10.1097/QAI.0000000000002 206.
9.J in, W., Wang, M., Wang, Y., Zhu, B., Wang, Q., Zhou, C., Li, P., Hu, C., Liu, J., Pan, J., Chen, J., & Hu, B. (2025). Targeted next-generation sequencing: a promising approach for Mycobacterium tuberculosis detection and drug resistance when applied in paucibacillary clinical sam ples. Microbiology spectrum, 13(7), e0312724. https:/ /doi.org/10.1128/spectrum.03127-24.
10. Mendelsohn, S. C., Fiore-Gartland, A., Penn-Nicholson, A., Mulenga, H., Mbandi, S. K., Borate, B., Hadley, K., Hikuam, C., Musvosvi, M., Bilek, N., Erasmus, M., Jaxa, L., Raphela, R., Nombida, O., Kaskar, M., Sumner, T., White, R. G., Innes, C., Brumskine, W., Hiemstra, A., … CORTIS-HR Study Team (2021). Validation of a host blood transcriptomic biomarker for pulmonary tuberculosis in people living with HIV: a prospective diagnostic and prognostic accuracy study. The Lancet. Global health, 9(6), e841–e853. https://doi.org/10.1016/S2214-109X(21)00045.
11. Mendelsohn, S. C., Fiore-Gartland, A., Penn-Nicholson, A., Mulenga, H., Mbandi, S. K., Borate, B., Hadley, K., Hikuam, C., Musvosvi, M., Bilek, N., Erasmus, M., Jaxa, L., Raphela, R., Nombida, O., Kaskar, M., Sumner, T., White, R. G., Innes, C., Brumskine, W., Hiemstra, A., … CORTIS-HR Study Team (2021). Validation of a host blood transcriptomic biomarker for pulmonary tuberculosis in people living with HIV: a prospective diagnostic and prognostic accuracy study. The Lancet. Global health, 9(6), e841–e853. https://doi.org/10.1016/S2214-109X(21)00045-0.
12. Van Hoving, D. J., Kenge, A. P., Maartens, G., & Meintjes, G. (2020). Point-of-Care Ultrasound Predictors for the Diagnosis of Tuberculosis in HIV-Positive Patients Presenting to an Emergency Center. Journal of acquired immune deficiency syndromes (1999), 83(4), 415–423. https://doi.org/10.1097/QAI.0000000000002279.
13. DeAtley, T., Hamada, Y., Baddeley, A., Werner, P., Kanchar, A., Zignol, M., & Rangaka, M. X. (2022). TB preventive treatment among pregnant women with HIV. The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease, 26(8), 727–732. https://doi.org/10.5588/ijtld.21.0477
14. Uplekar, M., Creswell, J., Ottmani, S. E., Weil, D., Sahu, S., & Lönnroth, K. (2013). Programmatic approaches to screening for active tuberculosis. The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease, 17(10), 1248–1256. https:// doi.org/10.5 588/ ijtld.13.0199
15. Chelkeba, L., Fekadu, G., Tesfaye, G., Belayneh, F., Melaku, T., & Mekonnen, Z. (2020). Effects of time of initiation of antiretroviral therapy in the treatment of patients with HIV/TB co-infection: A systemic review and meta-analysis. Annals of medicine and surgery (2012), 55,

148–158.https://doi.org/10.1016/j.amsu.2020.05.004

16. Kawuma, A. N., Wasmann, R. E., Dooley, K. E., Maartens, G., & Denti, P. (2023). Drug-drug interaction between rifabutin and dolutegravir: A population pharmacokinetic model. British journal of clinical pharmacology, 89(3), 1216–1221. https://doi.org/10.1111/bcp.15604
17. Stek, C., Schutz, C., Blumenthal, L., Thienemann, F., Buyze, J., Nöstlinger, C., Ravinetto, R., Wouters, E., Colebunders, R., Maartens, G., Wilkinson, R. J., Lynen, L., & Meintjes, G. (2016). Preventing Paradoxical Tuberculosis-Associated Immune Reconstitution Inflammatory Syndrome in High-Risk Patients: Protocol of a Randomized Placebo-Controlled Trial of Prednisone (PredART Trial). JMIR research protocols, 5(3), e173. https:// doi.org /10.2196 /resprot .6046
18. Shin, H. J., & Kwon, Y. S. (2015). Treatment of Drug Suscep - tible Pulmonary Tuberculosis. Tuberculosis and respiratory diseases, 78(3), 161–167. https:// doi.org /10.4046 /trd.2015.78.3.161
19. Chen, A. Z., Kumar, R., Baria, R. K., Shridhar, P. K., Subbar aman, R., & Thies, W. (2023). Impact of the 99DOTS digital adherence technology on tuberculosis treatment outcomes in North India: a pre-post study. BMC infectious diseases, 23(1), 504. https://doi.org/10.1186/s12879-023-08418-2
20. WHO consolidated guidelines on tuberculosis: Module 4: treatment - drug-resistant tuberculosis treatment, 2022 update [Internet]. Geneva: World Health Organization; 2022. Recommendations. Available from: https:/ /www.ncbi.nlm.nih.gov/books/NBK588557/
21. Imperial, M. Z., Nedelman, J. R., Conradie, F., & Savic, R. M. (2022). Proposed Linezolid Dosing Strategies to Minimize Adverse Events for Treatment of Extensively Drug-Resistant Tuberculosis. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America, 74(10), 1736–1747. https:// doi.org/ 10.1093 /cid/ciab699
22. Healan, A. M., Griffiss, J. M., Proskin, H. M., O'Riordan, M. A., Gray, W. A., Salata, R. A., & Blumer, J. L. (2017). Impact of Rifabutin or Rifampin on Bedaquiline Safety, Tolerability, and Pharmacokinetics Assessed in a Randomized Clinical Trial with Healthy Adult Volunteers. Antimicrobial agents and chemotherapy, 62(1), e00855-17. https://doi.org/10.1128/AAC.00855-17
23. Vinnard, C., & Macgregor, R. R. (2009). Tuberculous meningitis in HIV-infected individuals. Current HIV/AIDS reports, 6(3), 139–145. https:// doi.org/ 10.1007/ s11904-009-0019-7
24. Cherkos, A. S., LaCourse, S. M., Enquobahrie, D. A., Richardson, B. A., Bradford, S., Montepiedra, G., Mmbaga, B. T., Mbengeranwa, T., Masheto, G., Jean-Phillippe, P., Chakhtoura, N., Theron, G., Weinberg, A., Cassim, H., Raesi, M. S., Jean, E., Wabwire, D., Nematadzira, T., Stranix-Chibanda, L., Hesseling, A. C., … IMPAACT P1078 TB APPRISE Study Team (2023). Effect of pregnancy versus postpartum maternal isoniazid preventive therapy on infant growth in HIV-exposed uninfected infants: a post-hoc analysis of the TB APPRISE trial. EClinicalMedicine, 58, 101912.https://doi.org/10.1016/j.eclinm.2023.101912
25. Tran, C. H., Moore, B. K., Pathmanathan, I., Lungu, P., Shah, N. S., Oboho, I., Al-Samarrai, T., Maloney, S. A., Date, A., & Boyd, A. T. (2021). Tuberculosis treatment within differentiated service delivery models in global HIV/TB programming. Journal of the International AIDS Society, 24 Suppl 6(Suppl 6), e25809. https:// doi.org/ 10.1002/ jia2.25809
26. Van Der Meeren, O., Hatherill, M., Nduba, V., Wilkinson, R. J., Muyoyeta, M., Van Brakel, E., Ayles, H. M., Henostroza, G., Thienemann, F., Scriba, T. J., Diacon, A., Blatner, G. L., Demoitié, M. A., Tameris, M., Malahleha, M., Innes, J. C., Hellström, E., Martinson, N., Singh, T., Akite, E. J., … Tait, D. R. (2018). Phase 2b Controlled Trial of M72/ As0 - 1E Vaccine to Prevent Tuberculosis. The New England journal of medicine, 379(17), 1621–1634. https:// doi.org/10.1056/NEJMoa1803484

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