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Association Between Different Biomarkers and Initial Orthodontic Tooth Movement in Children and Adults: A Systematic Review and Meta-Analysis

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Abstract

The present systematic review aims to bridge the existing knowledge gap by evaluating the influence of various biomarkers on initial orthodontic tooth movement in children and adults. A systematic electronic search was conducted using relevant keywords across the databases PubMed, Google Scholar, and EBSCOhost to identify articles published in English until December 2023. The "Risk of Bias (ROB) in Non-randomized Studies of Interventions" (ROBINS-I) tool was used to assess the risk of bias, and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was applied to critically appraise the quality of evidence. A total of 10 studies were identified, all of which were non-randomised clinical trials that compared biomarker expression in patients belonging to the growing age group (children, juveniles, or adolescents) and adults, using gingival crevicular fluid (GCF) or saliva analysed by the ELISA method. Overall, younger patients consistently exhibited faster and more pronounced biological responses to orthodontic forces, with biomarker levels peaking within the first 72 hours of force application.

Categories: Dentistry
Keywords: cytokines, gingival crevicular fluid, interleukins, orthodontics, osteoprotegerin, saliva, tooth movement

Introduction And Background

Orthodontic treatment (OT) primarily involves the movement of teeth by inducing bone remodelling in the preferred direction. Bone remodelling refers to the resorption of the alveolar bone on one side of the socket and formation on the other, allowing the tooth to exhibit bodily movement within the alveolar bone of the jaw. While this is the end product, the process itself involves a complex cascade of cellular interactions down to the molecular level. The success of OT largely depends on these biological responses, which result from the interplay between undifferentiated mesenchymal cells and specialised cells such as fibroblasts, osteoblasts, and osteoclasts [1]. Mechanical forces induce the release of pro-inflammatory cytokines, growth factors, and enzymes that orchestrate bone resorption on the pressure side and bone formation on the tension side. Biomarkers such as receptor activator of nuclear factor kappa-B ligand (RANKL), osteoprotegerin (OPG), interleukins (IL-1β, IL-6), and prostaglandins (PGE2) play a pivotal role in regulating these processes [1,2]. RANKL actively stimulates osteoclasts to induce bone resorption, whereas OPG acts as a decoy receptor for RANKL, inhibiting its activity. Interleukins and PGE2 are pro-inflammatory cytokines that recruit inflammatory cells, initiating a cascade of bone resorption.

These cells and their biological mediators are abundant in younger individuals, accounting for a rapid bodily response. Thus, OT is preferably performed at a young age when there is still room for the growth of an individual at a favourable pace. However, for several reasons, the OT may get delayed beyond adolescence and the patients may seek it at a later stage during adulthood. These reasons include a lack of awareness or resources, fear of orthodontic treatment, reluctance to comply with long-term treatment, and limited access to healthcare facilities [3,4]. It is still important that treatment is carried out, as patients with malocclusions may face social stigma and humiliation, which can adversely affect their confidence and quality of life. Although not ideal, adult orthodontics remains necessary. Planning OT for adults is challenging due to the diminished remodelling capacity of the bone, reduced physiological response, vascular supply, biological mediators, and undifferentiated cells [5]. Consequently, performing OT in such individuals requires prolonged treatment durations given the slower rate of tooth movement.

Studying biomarkers in the adult population indicated for orthodontic treatment can aid orthodontists in making effective clinical decisions to optimise their treatment plans. Gingival crevicular fluid (GCF) and saliva serve as valuable diagnostic media for monitoring these biomarkers, which have also been studied during OT [6-8]. A recent systematic review identified fluctuations in RANKL, OPG, IL-1β, and PGE2 at different treatment stages, particularly after orthodontic activation [9]. However, the review concluded with low certainty that orthodontic tooth movement had little to no effect on salivary biomarkers. Despite the critical role of biomarkers in orthodontic tooth movement, a comprehensive understanding of their variations between children and adults remains lacking. While some studies have explored individual biomarkers in isolation, the interplay of multiple biomarkers in age-specific responses is yet to be thoroughly examined. Moreover, the non-invasive nature of GCF and saliva sampling makes them a preferable choice for researchers analysing biomarkers in large population samples.

The present systematic review aims to bridge the existing knowledge gap by evaluating the influence of various biomarkers on initial orthodontic tooth movement in children and adults. The objective of the review is to understand age-related differences in biomarker levels and their impact on orthodontic outcomes. This would aid orthodontists in tailoring optimal treatment plans for patients of different age groups.

Review

Methodology

Protocol Development

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [10]. The review protocol was registered in the Prospective Registration of Systematic Reviews (PROSPERO) under the identifier CRD42023480594. The review sought to answer the research question: “Is there any association between different biomarkers in GCF and initial orthodontic movements in children and adults?”

Search Strategy

A systematic electronic search was performed across the databases PubMed, Google Scholar, and EBSCOhost to identify relevant articles published in the English language from January 2000 to December 2023. The search was conducted using the following keywords and their combinations: “gingival crevicular fluid” (MeSH term) AND “orthodontic tooth movement” (MeSH term); “orthodontics” (MeSH term) AND “biomarkers” (MeSH term); “prostaglandins” (MeSH term) AND “cytokines” (MeSH term) AND “interleukins” (MeSH term); “children and adults” (MeSH term) AND “saliva” (MeSH term) AND “comparative study” AND “cross-sectional study” AND “prospective study” (MeSH term); “randomized controlled trials” (MeSH term).

To identify grey literature and unpublished clinical trials, Greylist and OpenGrey were used, and cross-referencing of the identified articles was performed. A manual search of orthodontic journals, including the *American Journal of Orthodontics and Dentofacial Orthopedics*, *Angle Orthodontist*, *European Journal of Orthodontics*, *Journal of Orthodontics*, *Journal of Oral Biology and Craniofacial Research*, and *Journal of Craniofacial Research*, was also conducted.

Selection of the Studies

Clinical studies, comparative studies, and prospective studies investigating the association between different biomarkers in GCF or saliva and initial orthodontic tooth movement in children and adults were included in the present systematic review. Only studies with full-text availability in the English language were considered. Reviews, abstracts, letters to the editor, editorials, animal-based studies, and in vitro studies were excluded. Studies with inadequate outcomes relevant to biomarker expression or ambiguity regarding study design were also excluded.

The authors (AR and PR) conducted a two-phase screening and selection of articles. The first phase involved mutual screening of titles and abstracts from the search results. Articles deemed eligible for inclusion were procured and subsequently screened independently by the authors (AR and PR) in the second phase for final inclusion in the review. In case of uncertainty regarding the selection of any study, authors SG and SP were consulted for their expertise. Corresponding authors of the respective articles were contacted via email to obtain any essential permissions or missing data.

Data Extraction

Data related to study samples (size, age, gender), selection criteria used by the authors, treatment methods employed, samples collected, and biomarkers assessed at various time points over a defined follow-up period were extracted independently from the included articles by two groups of authors (AR and SG, PR and SP). Any discrepancies were resolved through discussion and mutual agreement between the two groups.

Assessment of Risk of Bias and Quality of Evidence

Given the nature of the included studies, the “Risk of Bias (ROB) in Non-randomized Studies of Interventions” (ROBINS-I) tool was used to assess the risk of bias [11]. For the critical appraisal of the quality of evidence in each study included in the review, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was adopted [12].

Statistical Analysis

The standardised mean difference with a 95% confidence interval was calculated for continuous outcomes. The significance of any discrepancies in the estimates of the treatment effects across different trials was assessed using the Cochrane Handbook for Systematic Reviews for heterogeneity and the I^2 statistic [13]. A fixed-effects model (Mantel-Haenszel method) was used if no heterogeneity was observed ($p > 0.05$ or $I^2 \leqslant 24\%$); otherwise, a random-effects model (DerSimonian-Laird method) was applied [14,15]. All statistical analyses were performed using RevMan 5.3 (Cochrane Collaboration, Software Update, Oxford, UK). The significance level was set at $p < 0.05$.

Investigation of Publication Bias

To test for the presence of publication bias, the relative symmetry of the individual study estimates was assessed around the overall estimates using Begg's funnel plot. A funnel plot (plot of effect size versus standard error) was generated. Asymmetry in the funnel plot may indicate publication bias or biases related to sample size; however, it may also reflect a true relationship between trial size and effect size [16].

Results

Study Methods

The systematic review identified a total of 10 studies that satisfied the selection criteria (Figure *1*). The data extracted from the included studies are comprehensively summarised in Table *1* [17-26]. All these studies were non-randomised clinical trials that focused on comparing biomarker expression in patients belonging to the growing age group (children, juveniles, or adolescents) and adults. The levels of these biomarkers were analysed predominantly in GCF (n = 9), with the exception of Mann et al. (2019), who analysed them in the saliva of the subjects [22]. ELISA was the most commonly used method across eight studies, while one study each used enzyme immunoassay (EIA) and a biochemical assay [18,20].

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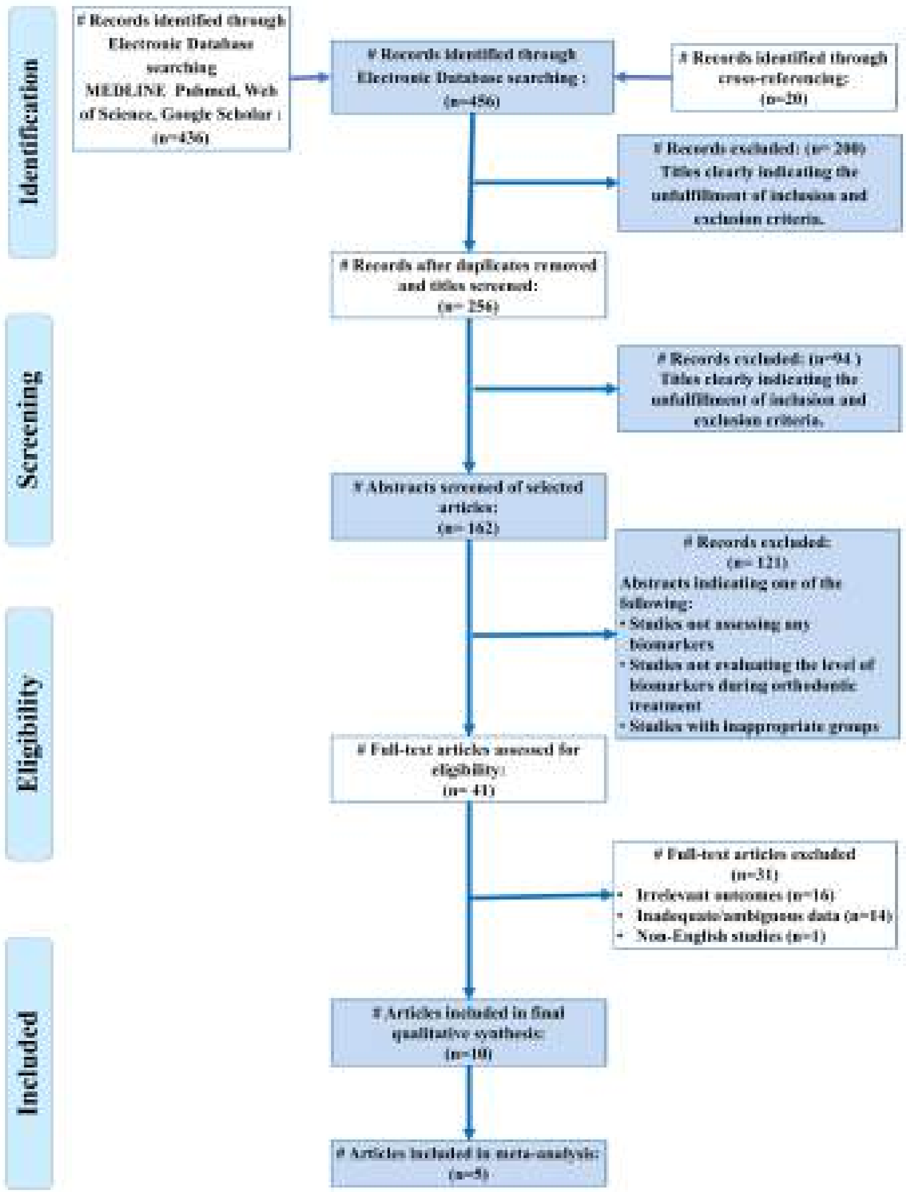

FIGURE 1: PRISMA flow diagram indicating the selection process of the articles in the present systematic review

PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis.

Author(s)	Country	Participants	Age (mean ± SD)	Gender Distribution	Selection Criteria	Intervention	Treatment Method	Samples Collected	Time Points	Biomarkers Studied	Follow-Up Period	Analysis Method	Key Findings	Conclusion	Limitations
Kawasaki et al. (2006) [17]	Japan	30 (15 C, 15 A)	C: 15.1 ± 2.8 years; A: 31 ± 3.6 years	C: 7 M, 8 F; A: 6 M, 9 F	Healthy periodontal tissues (probing depth ≤3 mm); no periodontal bone loss; no antibiotics or anti-inflammatory drugs in recent history	Retraction of upper canines using edgewise brackets and elastomeric chain delivering 250 g initial force	Edgewise brackets (0.018-inch slot); retraction along 0.018-inch archwire	GCF from the distal cervical margins of experimental and control teeth	0, 1, 24, and 168 hours after force application	RANKL, OPG	7 days	ELISA	• Juveniles: 1.23 mm movement; Adults: 0.82 mm. • RANKL ↑, OPG ↓ after 24h. • RANKL/OPG ratio higher in J.	• Tooth movement ↓ with age due to lower RANKL/OPG ratio in GCF.	• Small sample • Response variability.

Chibebe et al. (2009) [18]	Brazil	48 (25 C, 23 A)	C: 13.6 ± 2.1 years; A: 24.1 ± 2.1 years	C: 15 F, 10 M; A: 16 F, 7 M	Good general health; no anti-inflammatory drugs (2 months); no antibiotics (6 months); periodontally healthy; no smoking; required buccal/labial tooth movement as part of orthodontic treatment	Orthodontic brackets (GAC International) with 0.012 Nitinol wire delivering ~0.7 N force	Maxillary right lateral incisors with 0.012 Nitinol wire	GCF from the mesio/buccal gingival crevice of experimental teeth	Baseline (T0), 2 days, 21 days, 28 days	PGE2	28 days	EIA	• J: PGE2 ↑ baseline to 21d, ↓ after 21d. • A: PGE2 stable.	• PGE2 varies by age, linked to faster movement in juveniles.	• 28-day limit • Small sample • No analysis of other mediators.
Surlin et al. (2012) [19]	Romania	29 (16 C, 13 A)	C: 13.81 ± 0.98 years; A: 28.23 ± 3.37 years	C: 9 F, 7 M; A: 8 F, 5 M	Good general health; non-smokers; clinically and radiologically healthy periodontal tissues; no recent antibiotic or anti-inflammatory drug use; good oral hygiene; required upper canine distalisation with first premolar extraction	Application of orthodontic forces to upper canines using fixed appliances	Stainless steel 0.018" Roth brackets, 0.012" NiTi archwire, lacebacks, and transpalatal arch	GCF from test and control canines	-1 h (baseline), 4 h, 8 h, 24 h, 72 h, 1 week, 2 weeks	Pentraxin-3 (PTX-3)	2 weeks	ELISA	• PTX-3 peaked at 24h, returned baseline: 1w adults, 2w young. • Faster response in young.	• PTX-3 key in periodontal remodeling, faster in young.	• 2w follow-up • Small sample • Only 1 biomarker assessed.
Shetty et al. (2015) [20]	India	28 (14 C, 14 A)	C: 11 ± 4 years; A: 25 ± 5 years	NS	Fixed orthodontic therapy with bilateral first premolar extractions; no systemic diseases; no medication in past 3 months; good periodontal health; compliance with oral hygiene	Retraction of maxillary canines using Nickel Titanium coil springs	Fixed appliances with transpalatal arch reinforcement and retraction of canine using 0.018 stainless steel round wire	GCF from the maxillary right canine	Baseline, Day 7, Day 21, Day 42	Acid and alkaline phosphatases	6 weeks	Biochemical assays using semi-automated analyzer	• Alkaline phosphatase higher in children. • Acid phosphatase ↑ at Week 3.	• Faster movement in children linked to higher bone activity markers.	• Small sample • One biomarker • No long-term follow-up.
Vujacic et al. (2016) [21]	Serbia	20 (10 C, 10 A)	C: 13 ± 0.98 years; A: 20 ± 1.6 years	Gender distribution not specified	Good general health; no antibiotics within 3 months; no anti-inflammatory drugs within 1 month; healthy periodontium with 2 mm probing depth	Orthodontic elastic separators placed between the second premolars and first molars	Separator-induced tooth movement	GCF from treatment sites between the second premolar and the first permanent molar	Baseline, 24 h, 72 h, 168 h	IL-1β and IL-6	7 days	ELISA	• IL-1β, IL-6 peaked at 24h, 168h. • IL-6 ↑ more in children. • Tooth movement: C: 1.08 mm; A: 0.89 mm.	• IL-1β, IL-6 critical in early movement; children show faster cytokine responses.	• Small sample • No gender-specific analysis • Short follow-up.
Mann et al. (2019) [22]	India	20 (10 C, 10 A)	C: 12–18 years; A: >18 years	10 M, 10 F	Healthy patients; fixed orthodontic treatment; good oral hygiene; no systemic/periodontal diseases; no tobacco-related habits; no medication history	Fixed orthodontic appliance placement with 0.022-inch slots	Sequential archwire placement	Saliva	T0: Baseline; T1: 1 hour post first wire; T2: 1 month; T3: 1 hour post second wire	IL-1β, PGE2	1 month	ELISA	• PGE2, IL-1β ↑ at T1, ↓ at T2, ↑ at T3. • Levels higher in adults.	• Salivary IL-1β, PGE2 ↑ during ortho tx. • No pain difference between ages.	• Small sample • No malocclusion severity analysis • Short follow-up.
			C: 12–		Satisfactory general health, no antibiotics (6 months prior), no anti-inflammatory medication (1 month prior), no		Bonding and insertion of	GCF from	Baseline (before				• TNF-α, IL-1β ↑ post-tx,		• Small sample •

Afshar et al. (2020) [23]	Iran	20 (10 C, 10 A)	19 years; A: 20–33 years	13 F (65%), 7 M (35%)	periodontal disease (PD ≤ 3 mm, no attachment loss), Class I malocclusion, incisor irregularity index 3–6 mm, permanent dentition, no tooth removal in the treatment plan	Fixed orthodontic treatment with MBT 0.022 slot bracket system	0.014-inch NiTi archwire followed by sample collection	maxillary right central incisor (disto-labial aspect)	bonding), 24 hours, 7 days, 28 days after bonding	TNF-α and IL-1β	28 days	ELISA	peak 24h. • No significant age or gender differences.	• TNF-α, IL-1β levels ↑ during early ortho tx.	Uniform protocols • No analysis of other cytokines.
Chelărescu et al. (2021) [24]	Romania	20 (8 C, 12 A)	C: 11–16 years; A: 17–28 years	11 F (55%), 9 M (45%)	Indication for orthodontic treatment with premolar extraction, periodontal health (BPE score 0, no radiographic bone loss), no systemic diseases or medications	Fixed orthodontic treatment using MBT technique with metallic brackets and closed coil springs	Brackets bonded using Transbond XT and forces applied with 0.19 × 0.25 SS wires	GCF from distal gingival sulcus of maxillary canines	Baseline (T0), 24 hours after activation of orthodontic forces (T1)	IL1β and IL6	24 hours	ELISA	• IL1β ↑ T0 to T1, higher in adolescents (42.96 pg/μL vs. 17.93 pg/μL). • IL6 detectable in 1/3 sites.	• IL1β ↑ faster in adolescents, correlating with faster movement.	• 2 time points • Small sample • Low IL6 detection.
Afshar et al. (2021) [25]	Iran	20 (10 C, 10 A)	19.11 ± 6.23 years	14 F (70%), 6 M (30%)	Good general health, no recent antibiotics or anti-inflammatory use, absence of periodontal disease, Class I malocclusion, incisor irregularity index of 3–6 mm, permanent dentition, no extractions needed in treatment	Fixed orthodontic treatment with MBT 0.022-inch brackets and initial 14 NiTi archwire	GCF collected with paper strips from the gingival sulcus of maxillary central incisors	GCF from distolabial site	Baseline, 24 hours, 7 days, and 28 days after bonding	IL-8	28 days	ELISA	• IL-8 ↓ day 1, ↑ later but not to baseline. • No significant age or gender differences.	• IL-8 ↓ early, later ↑. • No significant age/gender differences.	• Small sample • Narrow age range • Short follow-up.
Kumar et al. (2022) [26]	India	20 (10 C, 10 A)	C: 11-16 years, A: 17-28 years	10 M, 10 F	Good periodontal health, no systemic diseases, no recent antibiotics or anti-inflammatory drugs, premolar extraction	fixed orthodontic treatment using 0.022 inch MBT brackets and 0.19 × 0.25 stainless steel wires and canine retraction using nickel-titanium closed coil springs	GCF collected using Periotron 8000 from the distal zone of canines	GCF from the distal zone of the canine	Baseline (T0), 24 hours after treatment (T1)	IL-1β, IL-6	24 hours	ELISA	• IL-1β ↑ baseline to 24h in both groups. • IL-6 detectable in 1/3 samples. • Adolescents: higher IL-1β vs YA.	• Adolescents show faster tissue response and higher IL-1β expression.	• Two time points (T0, T1) • Small sample • IL-6 undetectable in most cases.

TABLE 1: Data extracted from the studies included in the present systematic review

M: male, F: female, C/Ch: children, A: adults, J: juveniles, GCF: gingival crevicular fluid, BPE: basic periodontal examination, ELISA: enzyme-linked immunosorbent assay, EIA: enzyme immunoassay, MBT: McLaughlin, Bennett, Trevisi (bracket system), NiTi: nickel titanium, NS: not specified, OPG: osteoprotegerin, PD: probing depth, PGE2: prostaglandin E2, PTX-3: pentraxin-3, RANKL: receptor activator of nuclear factor kappa-B ligand, SD: standard deviation, SS: stainless steel, T0: baseline time point, T1: time point 1, TNF-α: tumour necrosis factor-alpha, ↑: increase, ↓: decrease, tx: treatment.

Study Samples

The sample size across the studies ranged from 20 to 48, with a total of 255 subjects included in the present systematic review. Six out of the 10 studies had a sample size of 20 subjects. An almost equal number of children and adults were considered across all studies (128 children and 127 adults). The age of children ranged from 11 to 19 years, while that of adults was less than 28 years, with the exception of Kawasaki et al. (2006), who reported a mean age of 31 ± 3.6 years for the adult population [17]. The studies were conducted on systemically healthy individuals with good periodontal health.

Orthodontic Interventions

Regarding the orthodontic aspect, alignment and levelling were carried out with nickel-titanium archwires in five studies, while canine retraction with nickel-titanium closed-coil springs was performed in three studies. Retraction of upper canines with elastomeric chains and tooth movement induced after placing separators were assessed in one study each, respectively. The follow-up period across the studies varied from 24 hours to one month.

The various biomarkers analysed included cytokines or pro-inflammatory mediators such as interleukins (IL-1β, IL-6, IL-8), tumour necrosis factor-alpha (TNF-α), prostaglandin E2 (PGE2), and those related to bone remodelling, including receptor activator of nuclear factor kappa-B ligand (RANKL), osteoprotegerin (OPG), pentraxin-3 (PTX-3), alkaline phosphatase, and acid phosphatase. Among the biomarkers studied, IL-1β was the most frequently analysed (n = 5 studies), followed by IL-6 (n = 3 studies) and PGE2 (n = 2 studies); the remainder were analysed in one study each, respectively.

Across multiple studies, younger patients (juveniles and adolescents) consistently demonstrated faster and more pronounced biological responses to orthodontic forces compared to adults. A higher expression of RANKL, OPG, alkaline phosphatase, acid phosphatase, IL-1β, and IL-6 was observed among individuals in the growing age group compared to adults [17,20,21,24]. Afshar et al. (2020, 2021) and Kumar et al. (2022) reported no significant differences in TNF-α, IL-1β, or IL-8 levels between males and females [23,26]. Kawasaki et al. (2006) and Vujacic et al. (2016) identified peaks in RANKL, IL-1β, and IL-6 at 24 to 168 hours post-force application [17,21]. Chelărescu et al. (2021) noted a significant increase in IL-1β at 24 hours in adolescents [24].

Temporal Trends in Biomarker Expression

Most studies observed a peak in biomarker levels shortly after the application of orthodontic force, followed by a gradual decline, particularly in adolescents. These trends align with the acute inflammatory response phase, characterised by the rapid recruitment of inflammatory mediators and bone remodelling markers.

Bone Remodelling and Orthodontic Perspective

The biomarkers studied, including RANKL, OPG, IL-1β, IL-6, PGE2, and alkaline phosphatase, are central to bone remodelling during orthodontic tooth movement. Kawasaki et al. (2006) emphasised the pivotal role of the RANKL/OPG axis in mediating osteoclast activity, with younger patients exhibiting faster bone resorption and deposition cycles [17]. Shetty et al. (2015) further corroborated this with elevated phosphatase levels in children, indicative of heightened bone turnover [20].

In the context of aseptic inflammation and tissue remodelling, Surlin et al. (2012) highlighted PTX-3 as a potential marker for monitoring early orthodontic responses [19]. Vujacic et al. (2016) and Mann et al. (2019) reinforced the importance of IL-1β and PGE2 in driving the inflammatory cascade and subsequent tooth movement [21,22].

Age- and Gender-Related Differences in Biomarker Expression

Kawasaki et al. (2006) reported higher levels of RANKL and lower OPG levels in juveniles, along with a significantly higher RANKL/OPG ratio [17]. Chibebe et al. (2010) found that juveniles exhibited greater fluctuations in PGE2 levels over the study period, peaking at 21 days, whereas adults showed stable levels [18]. These fluctuations may explain the faster tooth movement observed in younger patients. Vujačić et al. (2016) demonstrated significantly higher IL-1β and IL-6 levels in children compared to adults during the acute phase of orthodontic tooth movement, correlating with greater cytokine-mediated inflammation in younger participants [21]. Maan et al. (2019) observed elevated salivary IL-1β and PGE2 levels in adults compared to children during early orthodontic treatment [22]. However, pain perception did not significantly differ between the groups. No significant differences in biomarker expression were observed based on gender across the studies [23,25].

Time-Dependent Changes in Biomarkers

Studies consistently reported peak biomarker levels at 24-72 hours after orthodontic force application, followed by a gradual decline. Karimi-Afshar et al. (2021) observed a significant decrease in IL-8 levels on the first day post-treatment, followed by an increase over time, though baseline levels were not reached within the 28-day period [25]. Chelărescu et al. (2021) reported a significant increase in IL-1β at 24 hours for both adolescents and young adults, with the former demonstrating a greater response [24].

Biological Markers of Bone Remodelling

Surlin et al. (2012) highlighted the role of pentraxin-3 (PTX-3) in aseptic inflammation and periodontal remodelling. PTX-3 levels peaked earlier in younger participants, suggesting faster biological responses in juveniles compared to adults. Shetty et al. (2015) noted consistently higher levels of alkaline and acid phosphatases in children, reflecting heightened osteoblastic and osteoclastic activity during orthodontic tooth movement.

Overall Trends

Younger patients consistently exhibited faster and more pronounced biological responses to orthodontic forces, likely due to higher metabolic activity and cytokine expression in periodontal tissues. Biomarker levels peaked within the first 72 hours of orthodontic force application, suggesting this period is critical for assessing biological activity and optimising treatment interventions. While non-invasive sample collection methods (e.g., GCF and saliva) were effective, the variability in biomarker detection thresholds and analysis techniques warrants caution in interpreting findings.

Risk of Bias

The risk of bias assessment using the ROBINS-I tool indicated that most studies were classified as having a moderate risk of bias (Figure *2*). For instance, studies by Kawasaki et al. (2006) and Chibebe et al. (2010) lacked randomisation, blinding, and allocation concealment, introducing potential systematic bias [17,18]. Similarly, the study by Surlin et al. (2012) had issues with baseline differences and a limited sample size, which may have confounded the results [19]. The studies by Vujačić et al. (2016) and Karimi-Afshar et al. (2020) also demonstrated moderate bias due to their non-randomised design and incomplete reporting of strategies to minimise confounding [21,23]. Despite these limitations, all studies were methodologically adequate for observational research, providing detailed intervention and outcome measures.

FIGURE 2: Risk of bias across studies in the systematic review, individual (upper plot) and summary (lower plot)

Data taken from refs. [17-26].

GRADE Assessment

Using the GRADE approach, the quality of evidence across the studies ranged from low to moderate (Table *2*). Studies such as Kawasaki et al. (2006) and Surlin et al. (2012) were downgraded for imprecision due to their small sample sizes and wide confidence intervals, which limited the certainty of their findings [17,19]. Inconsistency was noted in the results of studies such as Chibebe et al. (2010) and Maan et al. (2019), where differing trends in biomarker levels were reported at similar time points [18,22]. Indirectness was low overall, as the studies directly addressed the review question regarding cytokine levels during orthodontic tooth movement. The likelihood of publication bias appeared low, given the lack of evidence for selective reporting in the included studies.

Author(s)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality
Kawasaki et al. (2006) [17]	Moderate	Low	Low	Moderate	Low	Moderate
Chibebe et al. (2009) [18]	Moderate	Low	Low	Moderate	Low	Moderate
Surlin et al. (2012) [19]	Moderate	Moderate	Low	High	Low	Low
Shetty et al. (2015) [20]	Moderate	Low	Low	Moderate	Low	Moderate
Vujacic et al. (2016) [21]	Moderate	Moderate	Low	High	Low	Low
Mann et al. (2019) [22]	Moderate	Low	Low	Moderate	Low	Moderate
Afshar et al. (2020) [23]	Moderate	Moderate	Low	Moderate	Low	Moderate
Chelărescu et al. (2021) [24]	Moderate	Moderate	Low	High	Low	Low
Afshar et al. (2021) [25]	Moderate	Low	Low	Moderate	Low	Moderate
Kumar et al. (2022) [26]	Moderate	Low	Low	Moderate	Low	Moderate

TABLE 2: Appraisal of quality of evidence by GRADE approach

GRADE: Grading of Recommendations Assessment, Development and Evaluation.

Synthesis of Results

The meta-analysis was conducted to evaluate the effect of biomarkers on the rate of initial orthodontic tooth movement between children and adults. Five studies containing data on 116 teeth subjected to initial orthodontic tooth movement under various biomarkers were included, with n = 58 teeth evaluated in the adult group and n = 58 teeth in the children/juvenile group for assessing the rate of initial orthodontic tooth movement [17,19,21,25,26].

As shown in Figure 3, the SMD is -1.26 (-2.26 to -0.25), and the pooled estimates favour adults, signifying that the overall rate of initial orthodontic tooth movement under the influence of biomarkers is, on average, 1.26 times greater in children. This difference is statistically significant (p < 0.05).

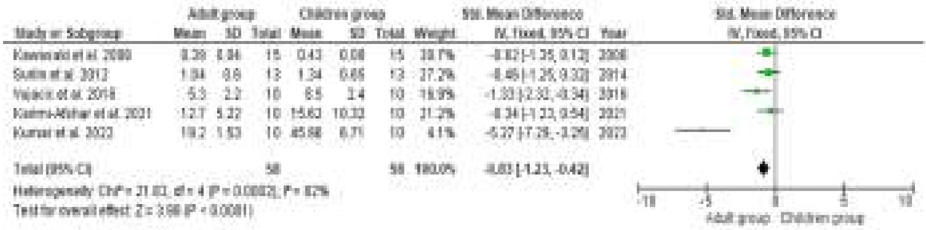

FIGURE 3: Rate of initial orthodontic tooth movement between adults and children

SD: standard deviation; CI: confidence Interval.

Data taken from refs. [17-26].

Publication Bias

The funnel plot showed significant asymmetry, indicating an absence of publication bias, as shown in Figure 4.

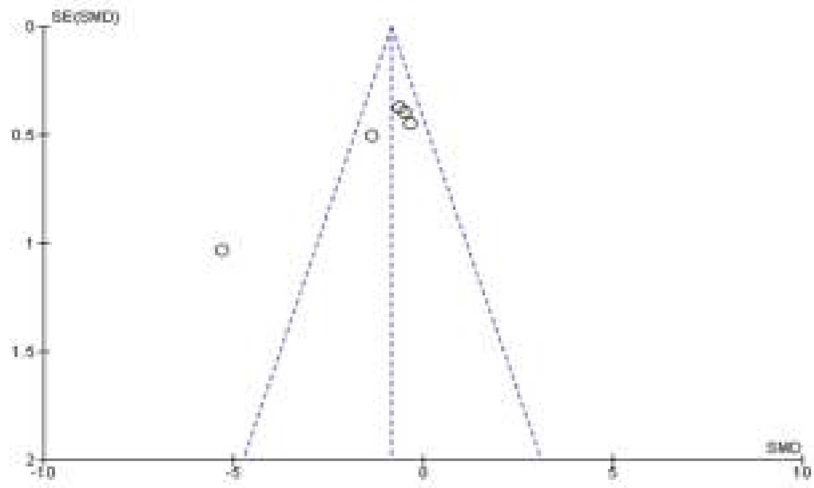

FIGURE 4: Begg's funnel plot with 95% confidence intervals indicating an absence of publication bias

Data taken from refs. [17-26].

Discussion

The biological processes underlying orthodontic tooth movement are complex, involving a complex interplay of biomolecular alterations. The findings of the present systematic review revealed the role of cytokines and mediators of bone remodelling during orthodontic tooth movement. Orthodontic forces create a microenvironment characterised by mechanical stress, which translates into biological signals. These signals activate cells within the periodontal ligament (PDL) and alveolar bone, initiating bone resorption on the pressure side and bone formation on the tension side. The markers investigated in the included studies were IL-1β, IL-6, IL-8, RANKL, OPG, PGE2, and PTX-3, which play a pivotal role in orchestrating these processes.

The cytokines IL-1β and IL-6 are among the first mediators released in response to mechanical loading of teeth [27]. IL-1β is a key pro-inflammatory cytokine responsible for upregulating osteoclast differentiation and activity through the RANKL pathway and was thus analysed in most of the studies [28]. Increased levels of IL-1β in the studies included in the present review correlate with enhanced bone resorption on the pressure side, facilitating tooth movement [21,26]. The findings that adolescents exhibit higher IL-1β levels than adults align with known age-related differences in cellular activity. Younger patients typically have a more robust inflammatory response due to greater PDL vascularisation, higher metabolic rates, and an abundance of progenitor cells capable of osteoclastogenesis [29].

IL-6 serves as both a pro-inflammatory mediator and a regulator of bone metabolism. It promotes osteoclast differentiation indirectly through the induction of RANKL expression in osteoblasts [30]. The transient elevation of IL-6 in GCF, as reported across the studies included in the present review, highlights its role in the early phase of tooth movement. However, its lower detectability in certain samples may reflect methodological limitations or variations in sample collection timing [24]. Likewise, IL-8 is an equally essential cytokine that functions as a chemoattractant for neutrophils and other immune cells. Its decrease during the first day of treatment may indicate the resolution of initial vascular changes and a shift towards sustained bone remodelling processes [25]. The subsequent increase in IL-8 levels at later time points suggests its role in recruiting cells involved in tissue repair and remodelling.

PGE2 is known for its role in amplifying inflammatory responses and enhancing osteoclastogenesis. The significant fluctuations in PGE2 levels in juveniles, as observed by Chibebe et al. (2010), further support the heightened inflammatory response in younger individuals [18]. The early recruitment and activation of osteoclast precursors correspond to the active phases of tooth movement.

The RANKL/OPG axis is central to bone remodelling. RANKL binds to its receptor on osteoclast precursors, promoting their differentiation and activation. OPG acts as a decoy receptor, inhibiting RANKL-RANK interactions and thereby regulating osteoclast activity. The findings by Kawasaki et al. (2006) that juveniles exhibit higher RANKL/OPG ratios than adults provide a mechanistic explanation for faster tooth movement in younger patients [17]. This age-related difference can be attributed to a more active bone remodelling environment in adolescents, supported by a higher RANKL availability relative to OPG [3,5,29].

PTX-3 is an acute-phase protein implicated in the regulation of aseptic inflammation and tissue remodelling [31]. Elevated PTX-3 levels observed within 24 hours of orthodontic movement initiation reflect its role in modulating the early inflammatory response [19]. The faster normalisation of PTX-3 levels in adults suggests a more restrained inflammatory milieu, which is consistent with age-related reductions in metabolic activity and cellular turnover.

Adolescents invariably exhibit more dynamic changes in biomarker levels compared to adults across the studies included in the present systematic review. This highlights the biological basis for age-related differences in orthodontic outcomes. Adolescents possess a more vascularised and cellular-rich PDL, which facilitates a rapid release of cytokines and recruitment of osteoclasts [29]. In contrast, adults experience a slower response due to reduced progenitor cell populations, decreased vascularity, and a denser alveolar bone structure [3,5].

These differences have direct clinical implications. Faster tooth movement in adolescents may necessitate adjustments in force magnitude and timing to avoid undesired side effects such as root resorption. Conversely, in adults, prolonged treatment durations may require adjunctive therapies, such as pharmacological modulation of bone remodelling or surgical acceleration techniques, to optimise outcomes.

While the reviewed studies provide valuable insights, several limitations should be addressed. Variations in study design, follow-up durations, and biomarker quantification methods hinder cross-study comparisons. The lack of randomised controlled trials further limits the strength of evidence. Future research should focus on standardised protocols for GCF collection, larger sample sizes, and extended follow-up periods. Additionally, exploring systemic factors such as hormonal influences and genetic predispositions will enhance our understanding of individual variability in biomarker expression and treatment outcomes.

Overall, the dynamic interplay of cytokines and bone remodelling mediators elucidates the biological mechanisms underlying orthodontic tooth movement. Age-related differences in biomarker expression highlight the need for personalised approaches to treatment planning and force application. By integrating biomarker-based monitoring into clinical practice, orthodontists can optimise treatment efficiency while minimising risks, paving the way for biologically driven orthodontic care.

Conclusions

Within their limitations, the findings of the present systematic review highlight the critical role of biomarkers such as IL-1β, IL-6, IL-8, RANKL, OPG, PGE2, and PTX-3 in mediating the biological processes of orthodontic tooth movement through their regulation of inflammation and bone remodelling. The findings consistently demonstrate age-related differences, with adolescents exhibiting heightened and more dynamic biomarker responses compared to adults, correlating with faster tooth movement and greater osteoclast activity. These differences emphasise the importance of individualised treatment approaches based on patient-specific biological profiles. While the evidence provides valuable insights into the molecular mechanisms of orthodontic therapy, the overall quality is constrained by methodological heterogeneity, limited sample sizes, and the absence of randomised controlled trials. Future studies with standardised protocols and extended follow-ups are warranted to strengthen the evidence base and further refine biomarker-guided orthodontic interventions.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Anisha Rajan CM, Sumeet Ghonmode, Suryakant Powar, Priya Rajput, Pallavi Chaudhary

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References

1. Gao Y, Min Q, Li X, et al.: Immune system acts on orthodontic tooth movement: cellular and molecular mechanisms. Biomed Res Int. 2022, 2022:9668610. 10.1155/2022/9668610
2. Inchingolo F, Inchingolo AM, Malcangi G, et al.: The interaction of cytokines in orthodontics: a systematic review. Appl Sci. 2024, 14:5133. 10.3390/app14125133
3. Christensen L, Luther F: Adults seeking orthodontic treatment: expectations, periodontal and TMD issues . Br Dent J. 2015, 218:111-7. 10.1038/sj.bdj.2015.46
4. Mathew R, Sathasivam HP, Mohamednor L, Yugaraj P: Knowledge, attitude and practice of patients towards orthodontic treatment. BMC Oral Health. 2023, 23:132. 10.1186/s12903-023-02780-y
5. Zhang Y, Yan J, Zhang Y, Liu H, Han B, Li W: Age-related alveolar bone maladaptation in adult orthodontics: finding new ways out. Int J Oral Sci. 2024, 16:52. 10.1038/s41368-024-00319-7
6. Fatima T, Khurshid Z, Rehman A, Imran E, Srivastava KC, Shrivastava D: Gingival crevicular fluid (GCF): a diagnostic tool for the detection of periodontal health and diseases. Molecules. 2021, 26:10.3390/molecules26051208
7. Nunes LA, Mussavira S, Bindhu OS: Clinical and diagnostic utility of saliva as a non-invasive diagnostic fluid: a systematic review. Biochem Med (Zagreb). 2015, 25:177-92. 10.11613/BM.2015.018
8. Tarallo F, Chimenti C, Paiella G, Cordaro M, Tepedino M: Biomarkers in the gingival crevicular fluid used to detect root resorption in patients undergoing orthodontic treatment: a systematic review. Orthod Craniofac Res. 2019, 22:236-47. 10.1111/ocr.12329
9. Rodrigues R, Mesquita CM, Alves HB, et al.: Changes in salivary biomarkers of pain, anxiety, stress, and inflammation related to tooth movement during orthodontic treatment: a systematic review. Dental Press J Orthod. 2024, 29:e242436. 10.1590/2177-6709.29.6.e242436.oar
10. Tugwell P, Tovey D: PRISMA 2020. J Clin Epidemiol. 2021, 134:A5-6. 10.1016/j.jclinepi.2021.04.008
11. Jeyaraman MM, Rabbani R, Al-Yousif N, et al.: Inter-rater reliability and concurrent validity of ROBINS-I: protocol for a cross-sectional study. Syst Rev. 2020, 9:12. 10.1186/s13643-020-1271-6
12. Granholm A, Alhazzani W, Møller MH: Use of the GRADE approach in systematic reviews and guidelines . Br J Anaesth. 2019, 123:554-9. 10.1016/j.bja.2019.08.015
13. Higgins JP, Thompson SG: Quantifying heterogeneity in a meta-analysis . Stat Med. 2002, 21:1539-58. 10.1002/sim.1186
14. Efthimiou O, Rücker G, Schwarzer G, Higgins JP, Egger M, Salanti G: Network meta-analysis of rare events using the Mantel-Haenszel method. Stat Med. 2019, 38:2992-3012. 10.1002/sim.8158
15. DerSimonian R, Laird N: Meta-analysis in clinical trials revisited . Contemp Clin Trials. 2015, 45:139-45. 10.1016/j.cct.2015.09.002
16. Afonso J, Ramirez-Campillo R, Clemente FM, Büttner FC, Andrade R: The perils of misinterpreting and misusing “publication Bias” in meta-analyses: an education review on funnel plot-based methods. Sports Med. 2024, 54:257-69. 10.1007/s40279-023-01927-9
17. Kawasaki K, Takahashi T, Yamaguchi M, Kasai K: Effects of aging on RANKL and OPG levels in gingival crevicular fluid during orthodontic tooth movement. Orthod Craniofac Res. 2006, 9:137-42. 10.1111/j.1601-6343.2006.00368.x
18. Chibebe PC, Starobinas N, Pallos D: Juveniles versus adults: differences in PGE2 levels in the gingival crevicular fluid during orthodontic tooth movement. Braz Oral Res. 2010, 24:108-13. 10.1590/s1806-83242010000100018
19. Surlin P, Rauten AM, Silosi I, Foia L: Pentraxin-3 levels in gingival crevicular fluid during orthodontic tooth movement in young and adult patients. Angle Orthod. 2012, 82:833-8. 10.2319/072911-478.1
20. Shetty SV, Patil AK, Ganeshkar SV: Assessment of acid phosphatase and alkaline phosphatase in gingival crevicular fluid in growing and adult orthodontic patients: An in vivo study. J Ind Orthod Soc. 2015, 49:10-4.
21. Vujačić A, Konić A, Pavlović J, Todorović V, Glibetić M: Differences in IL-1b and IL-6 levels in the gingival crevicular fluid during acute acute phase of orthodontic tooth movement between juveniles and young adult. Vojinosanitetski Pregled. 2016, 140:1-18. 10.2298/VSP150425178V
22. Maan AS, Patil AK: Assessment of salivary interleukin-1β (IL-1β), prostaglandin E(2) (PGE(2)) levels and pain intensity in children and adults during initial orthodontic treatment. J Orthod Sci. 2019, 8:16. 10.4103/jos.JOS_13_19
23. Afshar MK, Safarian F, Torabi M, Farsinejad A, Mohammadzadeh I: Comparison of TNF-α and IL-1β concentrations in gingival crevicular fluid during early alignment stage of orthodontic treatment in adults and adolescents. Pesqui Bras Odontopediatria Clin Integr. 2020, 20:0004. 10.1590/pboci.2020.086
24. Chelărescu S, Şurlin P, Decusară M, et al.: Evaluation of IL1β and IL6 gingival crevicular fluid levels during the early phase of orthodontic tooth movement in adolescents and young adults. Appl Sci. 2021, 11:521. 10.3390/app11020521
25. Karimi-Afshar M, Torabi M, Abdollahi S, Safarian MS, Farsinejad A: A comparative study on the IL-8 expression in gingival crevicular fluid during early alignment stage of orthodontic treatment in adults and adolescents. J Kerman Univ Med Sci. 2021, 28:367-73. 10.22062/jkmu.2021.91717
26. Kumar BD, Singh N, Verma SK, Singh S, Thakur S: A study to evaluate IL1 and IL6 gingival crevicular fluid levels in adolescents and young adults during the early phase of orthodontic tooth movement. J Pharm Bioallied Sci. 2022, 14:S494-7. 10.4103/jpbs.jpbs_52_22
27. Kitaura H, Kimura K, Ishida M, Sugisawa H, Kohara H, Yoshimatsu M, Takano-Yamamoto T: Effect of cytokines on osteoclast formation and bone resorption during mechanical force loading of the periodontal membrane. ScientificWorldJournal. 2014, 2014:617032. 10.1155/2014/617032
28. Mo Q, Zhang W, Zhu A, Backman LJ, Chen J: Regulation of osteogenic differentiation by the pro-

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inflammatory cytokines IL-1β and TNF-α: current conclusions and controversies. Hum Cell. 2022, 35:957-71. 10.1007/s13577-022-00711-7

29. Wang J, Huang Y, Chen F, Li W: The age-related effects on orthodontic tooth movement and the surrounding periodontal environment. Front Physiol. 2024, 15:1460168. 10.3389/fphys.2024.1460168
30. Wu Q, Zhou X, Huang D, Ji Y, Kang F: IL-6 enhances osteocyte-mediated osteoclastogenesis by promoting JAK2 and RANKL activity in vitro. Cell Physiol Biochem. 2017, 41:1360-9. 10.1159/000465455
31. Erreni M, Manfredi AA, Garlanda C, Mantovani A, Rovere-Querini P: The long pentraxin PTX3: a prototypical sensor of tissue injury and a regulator of homeostasis. Immunol Rev. 2017, 280:112-25. 10.1111/imr.12570

Original Article

DEVELOPMENT AND VALIDATION OF A TRILINGUAL QUESTIONNAIRE ASSESSING SOCIOECONOMIC BURDEN OF ORTHODONTIC TREATMENT IN INDIA

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ABSTRACT

Orthodontic care, though essential for functional and psychosocial health, often imposes a considerable socioeconomic burden on patients and families, especially in low- and middle-income countries. To quantify this multidimensional burden, a reliable and culturally relevant assessment tool is needed. A semi-structured questionnaire was developed through literature review and expert consultation. Face and content validity were established by a panel of five experts. Forty people from Wardha and Mumbai participated in the tool's pilot test. Cronbach's alpha was used to measure internal consistency, and intraclass was used to measure test-retest reliability Correlation coefficients (ICCs). Construct validity was confirmed via Principal Component Analysis (PCA), and criterion validity was assessed against self-rated burden scores. The questionnaire demonstrated excellent internal consistency (Cronbach's $\alpha = 0.89$) and test-retest reliability (ICC = 0.91). PCA identified five meaningful components explaining 72.5% of the variance. Significant relationships were observed between criterion validity and perceived burden scores. ($p < 0.001$). The validated trilingual questionnaire is a reliable and comprehensive tool for assessing the socioeconomic impact of orthodontic treatment in diverse Indian populations and is ready for use in large-scale epidemiological studies.

Key words: Direct costs, Indirect costs, Socioeconomic burden, Orthodontic treatment, Validation.

Introduction

Orthodontic treatment is frequently considered a critical component of oral healthcare, as it ensures functional harmony and appropriate occlusion, in addition to improving appearance. Due to the significant financial, practical, and psychological expenses associated with orthodontic treatment, many Indians continue to find it difficult to access it, despite its clinical importance [1]. These issues are especially undesirable for families with middle- or lower-income, where prolonged treatment times, high out-of-pocket costs, and limited insurance coverage can cause a lot of financial stress, cause people to discontinue treatment, or make them wait longer to get care.

In addition to direct costs, including consultation fees, diagnostic tests, and appliance costs, orthodontic treatment has a complex financial burden that includes indirect costs such as travel, neglected work or school days, and additional expenses for healthcare [2, 3]. Furthermore, the overall effect of treatment may be worsened by the psychological and emotional impact that patients and their families undergo, especially in underserved or semi-rural areas. Few studies have fully evaluated the socioeconomic and psychosocial aspects of those receiving orthodontic care, even though many have examined the clinical results of orthodontic interventions [2, 4, 5], as well as fewer have performed so in the Indian context [1]. One significant obstacle to filling this research gap is the lack of a validated instrument for evaluating the intricate burden of orthodontic treatment across diverse demographic and regional contexts. The majority of recently developed methods either only take clinical indicators into account or do not adequately account for linguistic and cultural diversity [5, 6]. A standardised, multilingual tool that accurately captures the actual situations of orthodontic patients and their families is essential, particularly in light of India's language diversity and differences in socioeconomic status between urban and rural populations. Therefore, the main objective of the current study was to develop and validate a trilingual (English, Hindi, and Marathi) questionnaire that would assess psychological impacts, indirect costs, socioeconomic load, and accessibility challenges related to orthodontic treatment.

Materials and Methods

Study design

In order to evaluate the socioeconomic and psychological impact of orthodontic treatment in both urban and rural Indian populations, a thorough questionnaire was developed and validated. Face validity and content formed part of the validation procedure. Validity, reliability evaluation, construct validity, and criterion validity, after which a pilot study is conducted to test viability and real-world application. The Institutional Ethics Committees of each participating institution provided their ethical clearance. All adult participants and minors' parents or guardians provided written informed consent. Confidentiality of participant data and secure preservation of all study materials guaranteed confidentiality.

Questionnaire development

A semi-structured questionnaire was initially developed following an extensive review of existing research and conceptual frameworks on healthcare access, financial burden, and psychosocial stress associated with long-term treatments such as orthodontic care. The parts were created to include five broad domains:

1. Demographic and Clinical Information
2. Direct Costs (diagnosis, appliances, consultation)
3. Indirect Costs (travel, accommodation, wage loss)
4. Psychological Impact and Coping Strategies
5. Accessibility, Affordability, and Systemic Factors

To ensure linguistic and conceptual comparison, items were initially written in English while being translated into Hindi and Marathi using a forward-backward translation approach by fluent specialists.

Face and content validation

The initial questionnaire draft was evaluated for clarity, relevance, and cultural compatibility by a panel of five subject matter experts, comprising orthodontists and public health professionals.

This stage assessed both face validity (the apparent appropriateness of items) and content validity (the degree to which items comprehensively represent the construct domains).

The initial version of the questionnaire was evaluated by a panel of five domain experts comprising three orthodontists, one public health dentist, and one sociologist. Each expert independently assessed the questionnaire for clarity, comprehensibility, and cultural appropriateness in English, Hindi, and Marathi. Experts reviewed a total of 42 items spanning five domains (demographic details, clinical factors, direct cost, indirect cost, and psychosocial impact). They rated each item using a 4-point Likert scale: 1 = Not clear, 2 = Needs major revision, 3 = Needs minor revision, 4 = Very clear. Items receiving a rating of 3 or 4 from at least 80% of the experts were considered to have acceptable face validity.

To assess content validity, the same panel of five subject matter experts evaluated the questionnaire items for relevance, completeness, and representativeness with respect to the constructs being measured—namely socioeconomic burden, clinical need, and psychosocial impact of orthodontic treatment. Each item was rated on a 4-point Likert scale as 1 = Not relevant, 2 = Somewhat relevant, 3 = Quite relevant, 4 = Highly relevant. The Item-level Content Validity Index (I-CVI) was calculated as the proportion of experts rating the item as either 3 or 4. An I-CVI of 0.80 or higher was considered acceptable. The Scale-level CVI (S-CVI/Ave) was computed as the average of I-CVI values across all items. Minor revisions were made based on expert feedback, such as rephrasing items for clarity, reducing ambiguity, and ensuring relevance to the socioeconomic context of both urban (Tier 1) and semi-rural (Tier 3) populations.

Pilot testing and sample characteristics

Following expert review, the revised questionnaire was administered to a pilot sample of 150 orthodontic patients—75 from Mumbai (Tier 1 city) and 75 from Wardha (Tier 3 city). Participants were selected using stratified random sampling to ensure representation across different income levels, genders, and types of treatment centers (private, government, trust hospitals). The age range was 10–22 years, with a mean age of 14.5 years. An equal number of male and female participants were included in each city to minimize gender bias.

Administration and language adaptation

Face-to-face interviews were conducted by trained field investigators fluent in all three study languages. The interviews lasted between 30 to 45 minutes and were conducted in participants' preferred language (English, Hindi, or Marathi). Interviewers were instructed to document participant difficulties, hesitations, or requests for clarification to assess comprehensibility.

Reliability testing

Internal consistency: Cronbach's alpha was calculated for each questionnaire domain and for the overall instrument to assess the degree to which items within a domain measured the same construct.

Test-retest reliability: A subsample of 40 participants (20 from each city) was re-administered the questionnaire after a two-week interval. To evaluate the stability of the responses over time, intraclass correlation coefficients (ICCs) were used.

Construct validity

Principal Component Analysis (PCA) was performed using responses from Phase I of the validation study with the aim of evaluating the construct validity of the questionnaire and evaluating if the items accurately represented the theoretical aspects of the socioeconomic burden of orthodontic treatment.

By recognising underlying components in the dataset, this statistical technique established sure that the questionnaire measured the intended distinct conceptual domains. To evaluate the questionnaire's underlying structure and determine whether its design accurately represented the theoretical aspects of the socioeconomic burden of orthodontic treatment, Principal Component Analysis (PCA) was applied. PCA aids in identifying clusters of similar items and decreases dimensionality while maintaining variance in data [7]. The responses obtained during the questionnaire's validation phase were investigated. The 20-item questionnaire was administered to PCA using Statistical Product and Service Solutions (SPSS Version 27.0). The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity were used to evaluate the acceptability of the data for factor extraction and the adequacy of the sampling. The ideal number of components was ascertained by analysing a scree plot using components with eigenvalues greater than 1. Items with factor loadings above 0.5 were considered significant contributors to a component.

Criterion validity

Criterion validity was assessed to evaluate how well the newly developed questionnaire corresponded with established external benchmarks related to socioeconomic and psychological impacts of healthcare burden. This was essential to ensure that the instrument not only demonstrated internal consistency and construct integrity but also accurately reflected real-world outcomes associated with financial and emotional challenges in orthodontic treatment.

To establish criterion validity, the following comparisons were made:

- *Socioeconomic burden domain vs. household income*
  - Items measuring direct and indirect costs (e.g., treatment fees, diagnostic costs, travel expenses) were correlated with self-reported household income levels.
  - It was hypothesized that respondents from lower income brackets would report higher financial strain scores, validating the socioeconomic sensitivity of the questionnaire.
- *Psychological impact domain vs. general stress levels*
  - Responses in the psychological domain (e.g., emotional distress, perceived burden on family, coping behaviors) were compared against self-rated stress levels on a 10-point visual analog scale (VAS).
  - It was expected that individuals scoring higher on financial and indirect burden would also report higher perceived stress, confirming the predictive association.

- *Indirect costs domain vs. travel time*
  - Indirect cost items (loss of wages, travel expenses, time spent) were tested for correlation with total reported travel time (in minutes) to the treatment center.
  - A positive correlation was expected, as longer travel durations typically contribute to greater financial and logistical strain.

Feasibility assessment

Participants were also asked to rate the questionnaire's clarity, length, and relevance. Interviewers provided qualitative feedback regarding participant engagement, logistical challenges, and time taken for completion.

Results and Discussion

Participant demographics

The pilot phase included 150 participants, with an equal distribution between Tier 1 (Mumbai) and Tier 3 (Wardha) cities. Participants were evenly split by gender (50% male, 50% female) and represented diverse socioeconomic strata. The mean age was 14.5 years (SD = 3.2), with an age range of 10 to 22 years **(Figure 1)**.

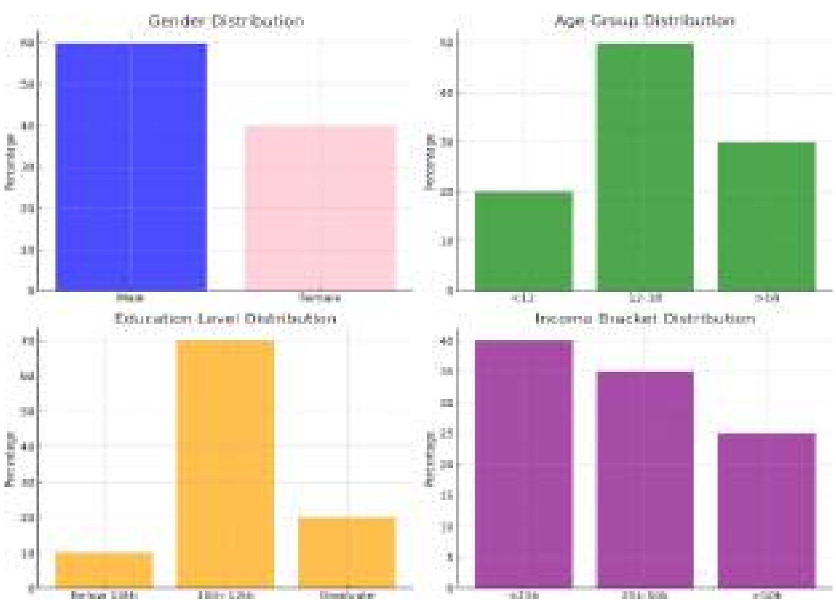

Figure 1. Demographic Characteristics of the pilot population

Internal consistency

The questionnaire demonstrated strong internal consistency, with an overall Cronbach's alpha of 0.89. Section-specific reliability coefficients ranged from 0.81 to 0.92, with the highest reliability observed in the domain assessing indirect costs **(Table 1)**. These findings indicate that the items within each section coherently measure their intended constructs.

Table 1. Internal Consistency

Section	Cronbach's Alpha
Demographic Information	0.81
Clinical Information	0.88
Direct Costs	0.85
Indirect Costs	0.92
Psychological Impact and Coping Mechanisms	**0.87**

Test–retest reliability

Temporal stability was assessed using intraclass correlation coefficients (ICCs) based on responses from a subset of 20 participants re-interviewed after two weeks. The overall ICC was 0.91 (95% CI: 0.85–0.96), and section-wise ICCs ranged from 0.88 to 0.94, demonstrating excellent test–retest reliability across all domains **(Table 2)**.

Table 2. Test-Retest Reliability

Section	Intraclass Correlation Coefficient (ICC)
Demographic Information	0.88
Clinical Information	0.9
Direct Costs	0.89
Indirect Costs	0.94
Psychological Impact and Coping Mechanisms	**0.91**

Feasibility and comprehensibility

Participant feedback supported the acceptability of the questionnaire, with 92% reporting ease of understanding and 96% affirming its relevance to their lived experiences. A small proportion (8%) indicated confusion regarding terminology associated with indirect expenses; these concerns were addressed through language simplification in the final version. Interviews were completed in an average of 32 minutes (SD = 7.1), and no significant logistical barriers were encountered during administration.

Preliminary insights from the pilot study

Pilot interviews revealed contextual variability in socioeconomic burden between Tier 1 and Tier 3 settings:

- *Direct costs:* Higher expenses for diagnostics and orthodontic appliances were reported in Mumbai compared to Wardha, suggesting city-based disparities in service pricing.
- *Indirect costs:* Wardha participants frequently cited substantial travel and lodging expenses when accessing urban healthcare facilities.
- *Coping mechanisms:* Respondents reported delaying other household expenditures, including food and education, and relying on informal financial support such as family borrowing.
- *Psychological impact:* Emotional stress due to financial strain was a common theme, especially among respondents from lower-income households in Tier 3 regions.

Revisions to the questionnaire

Revisions made following the pilot study included:

- Simplifying terminology related to indirect expenses.
- Adding examples and contextual prompts to items on coping strategies.
- Reducing redundancy in socioeconomic variables such as parental occupation and education.

Face validity

Overall, 39 of the 42 items (92.9%) met this threshold **(Table 3)**. The remaining 3 items, about travel-related indirect costs and definitions of "coping mechanisms," were revised for linguistic clarity and contextual alignment. All experts agreed that the questionnaire was visually well-structured and that the questions were logically sequenced. Font size, layout, and bilingual formatting were deemed acceptable for the target age group (10–22 years) and their caregivers. Feedback led to minor linguistic refinement of Marathi and Hindi versions to enhance idiomatic accuracy and cultural resonance.

Table 3. Expert Ratings of Face Validity Across Domains

Domain	No. of Items	Items Rated “Clear” or “Very Clear” (%)	Items Revised (n)
Demographic Details	6	100%	0

Clinical Characteristics	5	100%	0
Direct Costs	10	90%	1
Indirect Costs	12	83.3%	1
Psychological Impact and Coping Mechanism	9	88.9%	1
Total	42	92.9%	**3**

Content validity

Of the 42 items evaluated, 40 achieved an I-CVI ≥ 0.80. Two items (one related to "temporary job loss" and another concerning "delayed education expenses") initially received lower ratings due to ambiguity and perceived overlap [8]. These items were revised for clarity and specificity in the final questionnaire [9-12].

The overall S-CVI/Ave of 0.91 reflects a high level of expert agreement, confirming that the questionnaire is well-aligned with the study constructs and appropriately captures the multidimensional aspects of socioeconomic burden in orthodontic care **(Table 4)**.

Table 4. Content Validity Index (CVI) Ratings

Domain	No. of Items	I-CVI Range	Mean CVI	I-S- CVI/Ave
Demographic Details	6	1.00	1.00	1.00
Clinical Characteristics	5	0.80–1.00	0.92	0.92
Direct Costs	10	0.80–1.00	0.88	0.88
Indirect Costs	12	0.80–1.00	0.87	0.87
Psychological Impact and Coping Mechanism	9	0.80–1.00	0.89	0.89
Total	42	0.80–1.00	0.91	0.91

Construct validity

Sampling adequacy and suitability

Before conducting PCA, the adequacy of the sample and suitability of the data for factor analysis were assessed. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.842, which exceeds the recommended threshold of 0.6, indicating that the sample was Adequate for PCA. Bartlett's Test of Sphericity was statistically significant ($p < 0.001$), confirming that the inter-item correlations were sufficiently large for PCA.

Component extraction and scree plot

PCA revealed five components with eigenvalues greater than 1, collectively accounting for 72.5% of the total variance in the dataset **(Table 5)**. Analysis of the scree plot supported this five-factor solution, showing a distinct inflection point after the fifth component, consistent with the theoretical domains of the questionnaire.

Table 5. Variance Explained by Principal Components

Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)
Component 1: Socioeconomic Burden	5.66	28.3	28.3
Component 2: Indirect Costs	3.52	17.6	45.9
Component3: Psychological Impact	2.04	10.2	56.1
Component 4: Accessibility	1.72	8.6	64.7
Component 5: Parental Influence	1.56	7.8	72.5

Table: Total Variance Explained by Principal Components

Rotated component matrix

A Varimax rotation **(Table 6)** was applied to improve the interpretability of the factor structure. Each of the five extracted components captured a distinct conceptual domain:

- Component 1 (Socioeconomic Burden): Included items related to income, education, and direct treatment costs.
- Component 2 (Indirect Costs): Included items measuring travel costs, time investment, and income loss due to appointments.
- Component 3 (Psychological Impact): Captured emotional distress, perceived family compromise, and coping behaviors.
- Component 4 (Accessibility and Affordability): Reflected items on treatment availability, facility preference, and financial assistance.

- Component 5 (Parental Education Influence): Included questions on parents' educational level and their role in treatment decisions.

Table 6. Rotated Component Matrix - Varimax Rotation (Item Loadings)

Item	C1	C2	C3	C4	C5
Income	0.8	–	–	–	–
Education	0.76	–	–	–	–
Direct Costs	0.82	–	–	–	–
Travel Costs	–	0.84	–	–	–
Loss of Income	–	0.77	–	–	–
Time Spent	–	0.81	–	–	–
Stress	–	–	0.79	–	–
Family Compromises	–	–	0.85	–	–
Coping Mechanisms	–	–	0.76	–	–
Facility Preferences	–	–	–	0.84	–
Financial Aid Options	–	–	–	0.78	–
Parental Knowledge	–	–	–	–	**0.8**
Parental Decision-Making	**–**	**–**	**–**	**–**	**0.74**

The results of PCA affirm that the questionnaire is structured around five distinct but interrelated domains, aligned with the theoretical construct of socioeconomic burden in orthodontic treatment. Notably, the clustering of psychological impact items as a separate component underscores the emotional consequences often overshadowed by financial considerations. Similarly, the emergence of accessibility and parental influence as standalone components emphasizes that decisions around orthodontic care are shaped not only by economic factors but also by social context and family dynamics. The construct validity of the Questionnaire is strongly supported by PCA findings. The five-component structure is both theoretically sound and empirically robust, indicating that the instrument successfully captures the multidimensional nature of the socioeconomic and emotional burden of orthodontic treatment.

Criterion validity

The Correlation Between Questionnaire Domains and External Criteria is summarized in **Table 7**.

- *Socioeconomic burden and household income*
  - A significant inverse correlation ($r = –0.49$, $p < 0.001$) was found between household income and financial burden scores.
  - Respondents from lower income groups consistently reported higher total scores on direct and indirect financial strain, confirming the instrument's capacity to discriminate based on economic background.

- *Psychological impact and stress levels*
  - A strong positive correlation ($r = 0.61$, $p < 0.001$) was observed between stress scores and the psychological impact domain.
  - This indicated that participants who reported financial constraints and lifestyle compromises also exhibited higher levels of self-reported stress and emotional fatigue.

- *Indirect Cost Domain and Travel Time*

The correlation between indirect cost scores and travel time was moderate but significant ($r = 0.42$, $p < 0.01$), validating that the items meaningfully captured logistical challenges contributing to the treatment burden.

Table 7. Correlation Between Questionnaire Domains and External Criteria

External Variable	Domain of Questionnaire	Correlation Coefficient(r)	Significance (p-Value)
Household Income	Socioeconomic Burden	0.49	<0.001
Self-rated Stress (VAS)	Psychological Impact	0.61	<0.001
Total travel time (in minutes)	Indirect Costs	0.42	<0.01

The questionnaire domains exhibit significant relationships with established indices of economic status, emotional well-being, and logistical load, which supports their criterion validity. The findings show that the measure accurately represents the real-world implications of orthodontic treatment, particularly in economically challenged and geographically underserved populations. Notably, the high correlation to stress confirms the inclusion of psychological factors into a traditionally economic construct, emphasising the multidimensional burden of prolonged dental procedures [13-17].

The criterion validity analysis demonstrates that the questionnaire accurately predicts and correlates with external measures of economic hardship, psychological stress, and treatment-related difficulties.

These findings support the use of this measure in larger epidemiological and interventional research to determine the financial and emotional effects of orthodontic treatment in various kinds of groups.

The current research presents the development and validation of a comprehensive questionnaire aimed at quantifying the socioeconomic burden of orthodontic treatment among Indian patients across varying linguistic and geographic contexts. The results provide evidence of the tool's construct, face, content, and criterion validity, indicating that it is suited to broader use in clinical and epidemiological research. Assessments of the questionnaire's psychometric strength, intelligibility, and relevance were conducted in Marathi, Hindi, and English. Both experts and target users found the questionnaire items to be well-understood, culturally sensitive, and relevant, as determined by face and content validity assessments. Expert suggestions highlighted a few minor terminological difficulties, especially in the areas that included indirect costs and psychosocial coping. Iterative refinement significantly resolved these problems, yielding good content validity indices and high agreement scores.

This process reflects the critical role of interdisciplinary expert panels in achieving linguistic and conceptual clarity during tool development [18].

Construct validity, established through PCA [7], revealed five distinct components accounting for over 70% of the total variance. These components – socioeconomic burden, indirect costs, psychological impact, accessibility and affordability, and parental educational influence – are theoretically aligned with existing literature on healthcare financial strain [1, 19, 20]. Notably, the clustering of psychological impact items into a single factor underscores the interplay between financial hardship and emotional distress, a finding consistently reported in studies on chronic care burden. The emergence of "parental educational influence" as a standalone factor also points to the unique sociocultural context in which orthodontic care decisions are made [21].

The criterion validity of the questionnaire was assessed by correlating its financial burden scores with treatment intensity and provider-reported cost categories. Although a gold standard

Comparator was not available, moderate correlation with clinician-reported estimates supports the instrument's ability to capture cost-related nuances. The moderate agreement reflects methodological challenges commonly encountered when validating instruments against non-specific or non-standardized benchmarks. Nonetheless, the consistent directional trends affirm the tool's utility for comparative analyses.

In line with the TAWS-16 tool validation approach, our study also emphasized the importance of internal consistency and test-retest reliability [22]. Cronbach's alpha coefficients across domains ranged from 0.81 to 0.92, and ICCs were above 0.88 in all sections, indicating excellent reliability. These findings are consistent with the psychometric thresholds recommended for newly developed tools and suggest that the questionnaire is stable over time and across contexts [23, 24].

Importantly, this study addressed the challenges of multilingual deployment by translating and validating the tool in Hindi and Marathi – two widely spoken languages across the Maharashtra region of India [25, 26]. This aligns with previous recommendations advocating linguistic validation as a critical step for inclusivity and generalizability in health services research [27, 28].

The pilot study further confirmed the feasibility of deploying this questionnaire in real-world settings. Feedback from participants and interviewers suggested that the questionnaire was easy to administer and comprehensible across different educational and socioeconomic strata. The average interview duration of 32 minutes was deemed acceptable for use in clinical and community surveys. Such findings suggest high practical utility and adaptability of the tool for wider epidemiological application.

Collectively, the study reinforces the importance of adopting structured, validated instruments for measuring financial and psychosocial burdens in orthodontic care. As disparities in access and affordability of orthodontic services persist, particularly between Tier 1 and Tier 3 regions, tools such as this can guide policy, program planning, and resource allocation. The validated questionnaire is thus not only a research instrument but also a potential tool for routine screening in orthodontic settings, especially in public health and insurance-supported frameworks.

Future studies may consider validating the tool in additional regional languages and testing its responsiveness to policy interventions such as insurance inclusion or subsidy models [29]. Additionally, longitudinal applications of the questionnaire can provide insight into the evolving burden across the treatment timeline.

Conclusion

The present study successfully developed and validated a comprehensive, multilingual questionnaire designed to assess the socioeconomic burden of orthodontic treatment in Indian contexts. The final version demonstrated strong face and content validity as confirmed by subject experts, while construct validity was supported through principal component analysis, revealing a five-domain structure. High internal consistency and excellent test-retest reliability further confirmed the robustness of the tool. Criterion validity was established through significant correlations with external economic indicators. The questionnaire, available in English, Hindi, and Marathi, is both psychometrically sound and contextually appropriate for diverse linguistic populations. It may serve as a reliable instrument for clinicians, researchers, and policymakers aiming to quantify and address the socioeconomic challenges associated with orthodontic care.

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Written informed Consent was obtained from Study participants for participation in the study, and this study adheres well to all ethical guidelines.

References

1. Ghonmode S, Shrivastava S, Kadaskar AR, Bapat S. Socioeconomic burden of orthodontic treatment: a systematic review. Med Pharm Rep. 2023;96(2):154.
2. Nakhleh K, Joury E, Dean R, Marcenes W, Johal A. Can socioeconomic and psychosocial factors predict the duration of orthodontic treatment? Eur J Orthod. 2020;42(3):263–9.
3. Vieira MA, Lima LS, Leite IC. Access and financial impacts of public orthodontic provision on global health systems: integrative review. Rev Ciênc Plur. 2022;:e25225.
4. Schmahl T, Steinhäuser J, Goetz K. Association between orthodontic treatment and psychosocial factors in adolescents: a cross-sectional study. Eur J Orthod. 2025;47(1):cjae082.
5. Arrow P, Brennan D, Spencer AJ. Quality of life and psychosocial outcomes after fixed orthodontic treatment: a 17-year observational cohort study. Community Dent Oral Epidemiol. 2011;39(6):505–14.
6. Doğramacı EJ, Brennan DS. The long-term influence of orthodontic treatment on adults' psychosocial outcomes: an Australian cohort study. Orthod Craniofac Res. 2019;22(4):312–20.
7. Greenacre M, Groenen PJ, Hastie T, d'Enza AI, Markos A, Tuzhilina E. Principal component analysis. Nat Rev Methods Primers. 2022;2(1):100.
8. Thuy VTT, Hung DN, Oanh LTT, Tuyet VTA, Thu BT. Factors impact on business performance of enterprises: the case of Vietnam. J Organ Behav Res. 2023;8(2):27–39. doi:10.51847/2itmiM3CoE
9. Saeed MS, Almendeel HM. Perceptions of pharmacy students towards online learning during COVID-19 pandemic in Saudi Arabia. J Adv Pharm Educ Res. 2023;13(1):6–14. doi:10.51847/0QNajxm7pC
10. Mustarichie R, Saptarini NM. Sirih (Piper betle) folium as new candidate for anti-herpes virus: in-silico study. J Adv Pharm Educ Res. 2023;13(1):46–50. doi:10.51847/mcuhssaHlU
11. Yilmaz S, Ertürk M, Soydemir A, Erciyas A, Oran İB. Military implications of artificial intelligence - case of republic of Turkey. J Organ Behav Res. 2023;8(2):1–14. doi:10.51847/Tal2sc1FFp
12. Maralov VG, Sitarov VA, Kariyev AD, Krezhevskikh OV, Kudaka MA, Ageyeva LY, et al. Strategies of self-improvement for students with different agency levels. J Organ Behav Res. 2023;8(2):15–26. doi:10.51847/4cITyRcqSN
13. Aldhairyan AH, Alyami SSH, Alsaad AMS, Al Shuqayfah NI, Alotaibi NA, Mujammami NM, et al. Gastroesophageal reflux disease: diagnosis and management approach, literature review. World J Environ Biosci. 2022;11(1):1–3. doi:10.51847/EvuxMWxAai
14. Almuhanna MA, Alanazi MH, Ghamdi RNA, Alwayli NS, Alghamdi ISG, Qari AA, et al. Tachycardia evaluation and its management approach, literature review. World J Environ Biosci. 2022;11(1):4–8. doi:10.51847/7maH6sWjQy
15. Alhazmi RA, Khayat SK, Albakri MH, Alruwaili WS, Bayazed HA, Almubarak SA, et al. An overview on the assessment and management of polycystic ovarian syndrome. World J Environ Biosci. 2022;11(1):17–23. doi:10.51847/Yaaa2745ZY
16. Alsayed MA, Alhassan OMA, Alzahrany AM, Mutanbak HIM, Alamoudi AA, Eid SM, et al. An overview on lumbar disc herniation on surgical management approach. World J Environ Biosci. 2022;11(1):24–9. doi:10.51847/OJ2dQINEwx
17. Nezhadrahim A, Shahri MM, Akbari NN. Effects of the Roux-en-Y gastric bypass on DM and renal function in obese patients. J Adv Pharm Educ Res. 2023;13(1):1–5. doi:10.51847/c60nSRP6Q7
18. Hyrkäs K, Appelqvist-Schmidlechner K, Oksa L. Validating an instrument for clinical supervision using an expert panel. Int J Nurs Stud. 2003;40(6):619–25.
19. Smith L, Jack H, Antoun J, Fowler P, Blanch K, Foster Page L. The impact of treatment cost on low SES families: an orthodontic viewpoint. Aust Orthod J. 2019;35(1):13–20.

20. Lemasney NM, Mathur MR. Impact of socioeconomic status on children and adolescents’ orthodontic treatment: a systematic review. Community Dent Health. 2023;40(2):114–24.
21. Nobre R, Pozza DH. Parental influence in orthodontic treatment: a systematic review. Med Pharm Rep. 2023;96(1):28.
22. Roy R, Sukumar GM, Philip M, Gopalakrishna G. Face, content, criterion, and construct validity assessment of a newly developed tool to assess and classify work-related stress (TAWS–16). PLoS One. 2023;18(1):e0280189.
23. Monticone M, Galeoto G, Berardi A, Tofani M. Psychometric properties of assessment tools. InMeasuring spinal cord injury 2021 (pp. 7-15). Springer, Cham.
24. Swan K, Speyer R, Scharitzer M, Farneti D, Brown T, Woisard V, et al. Measuring what matters in healthcare: a practical guide to psychometric principles and instrument development. Front Psychol. 2023;14:1225850.
25. Shirbahadurkar SD, Bormane DS. Marathi language speech synthesizer using concatenative synthesis strategy (spoken in Maharashtra, India). In: 2009 Second International Conference on Machine Vision. IEEE; 2009. p. 181–5.
26. Kamat R, Ghate M, Gollan TH, Meyer R, Vaida F, Heaton RK, et al. Effects of Marathi-Hindi bilingualism on neuropsychological performance. J Int Neuropsychol Soc. 2012;18(2):305–13.
27. Muller-Botti S, Maestre JM, Del Moral I, Fey M, Simon R. Linguistic validation of the debriefing assessment for simulation in healthcare in Spanish and cultural validation for 8 Spanish-speaking countries. Simul Healthc. 2021;16(1):13–9.
28. Brandt BA, Angün Ç, Coyne KS, Doshi S, Bavendam T, Kopp ZS. LUTS patient reported outcomes tool: linguistic validation in 10 European languages. Neurourol Urodyn. 2013;32(1):75–81.
29. Hung M, Su S, Hon ES, Tilley E, Macdonald A, Lauren E, et al. Examination of orthodontic expenditures and trends in the United States from 1996 to 2016: disparities across demographics and insurance payers. BMC Oral Health. 2021;21(1):268.

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Comparative Assessment of Relapse Following Fixed Orthodontic Treatment in Patients Treated With and Without Extraction: A Systematic Review and Meta-Analysis

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Abstract

The present systematic review aimed to evaluate and compare the post-treatment relapse of overjet, overbite, and mandibular incisor crowding in patients treated with extraction and non-extraction orthodontic approaches and to assess the influence of treatment modality on long-term stability. The review was conducted following PRISMA guidelines. Data were extracted from 10 studies, including retrospective and longitudinal designs, with a total of 720 participants. The primary outcome measures included overjet, overbite, and Little's Irregularity Index. Standardized mean difference (SMD) was used as the summary statistic to compare extraction and non-extraction groups. The risk of bias was assessed using the ROBINS-I tool. The meta-analysis revealed no statistically significant differences in relapse between extraction and non-extraction groups for overjet (SMD: 0.52, 95% CI: -0.18 to 1.23, p>0.05), overbite (SMD: 0.41, 95% CI: -0.11 to 0.93, p>0.05), and incisor irregularity index (SMD: 0.71, 95% CI: -0 to 1.23, p>0.05). Funnel plots indicated no significant publication bias. Risk of bias assessment showed moderate concerns in confounding and participant selection across several studies, while bias due to missing data was notable in longer follow-up studies. The findings suggest that both extraction and non-extraction treatment approaches exhibit similar post-treatment relapse rates for overjet, overbite, and incisor irregularity. The choice of treatment should be based on clinical considerations along with concerns of long-term stability. Further high-quality randomized controlled trials are required to strengthen the evidence.

Categories: Dentistry
Keywords: extraction vs non-extraction, incisor crowding, meta-analysis, orthodontic relapse, overbite, overjet, systematic review

Introduction And Background

Dental extractions have been an inseparable part of orthodontic practice in cases where space gain is required, with premolars being the most commonly extracted teeth. However, the issue has been a matter of debate with many reports in favor of non-extraction orthodontic treatment. The practitioners supporting this notion believe that the extraction of premolars can have a more detrimental effect on the patient’s facial development than the actual malocclusion [1]. Additionally, while malocclusion is corrected during orthodontic treatment, there is alarming clinical evidence of post-treatment relapse, which is cause for concern [2,3].

The essence of orthodontic treatment lies in correcting the malocclusions present in the dentition. Equally important is to sustain the treatment outcomes and prevent future recurrence. It is universally known that relapse following orthodontic treatment is inevitable, and some amount of changes in the dentition will occur even after the treatment is completed [2]. Stabilizing the achieved corrections and preventing relapse is a challenge faced by orthodontists. Knowing the factors behind post-treatment relapse can greatly aid orthodontists in the determination of the treatment plan and its prognosis [4,5]. They will be better able to devise strategies to tackle the relapse after treatment.

Extractions followed by fixed orthodontic treatment are usually performed to correct overjet, overbite, and crowding. Some of the factors influencing relapse after overjet correction include the extent of incisal inclination during the treatment commencement, labial inclination of the maxillary incisors, interincisal angle, and lingual inclination of the mandibular incisors [6]. Likewise, factors responsible for relapse after overbite correction include overjet, the distance of displacement of incisors from their natural position, facial pattern and height, crowding, and the amount of overbite corrected [7].

Various systemic factors and the use of necessary systemic medications during and after the orthodontic treatment can influence its post-treatment outcomes and sustainability [8,9]. Because of the numerous factors influencing the post-treatment outcomes leading to relapse, many times, maintaining the achieved corrections is equally, or perhaps, more challenging than the treatment itself. It would cost the patients’ time and money to no benefit, and thus, the patients may lose confidence in the orthodontist when such an unfavorable event occurs. The prevention of relapse, therefore, starts at the time of treatment planning, even before the treatment has begun. Occlusal harmony, tooth-soft tissue relationships, space gain, and other such factors need to be meticulously considered before initiating a fixed orthodontic treatment plan [10,11]. In this regard, answering the question of whether gaining space by dental extractions is more beneficial compared to its collateral effects can play a pivotal role in deciding the treatment plan by the orthodontists.

Determining whether space gained through extractions provides greater long-term stability compared to its potential drawbacks remains a crucial consideration in orthodontic decision-making. Existing clinical literature presents conflicting evidence regarding the impact of extractions on post-treatment relapse. While some studies suggest that extraction therapy contributes to better long-term stability, others report no significant differences between extraction and non-extraction approaches. Previous systematic reviews have attempted to address this issue, yet variability in study designs, follow-up durations, and relapse assessment methods has led to inconclusive findings. To clarify this controversy, the present systematic review aims to compare the extent and rate of relapse following the correction of overjet, overbite, and crowding with and without extractions in fixed orthodontic treatment. By synthesizing high-quality evidence, this review seeks to provide orthodontists with a clearer understanding of whether extraction or non-extraction treatment protocols offer superior long-term stability.

Review

Protocol development

The present systematic review was conducted and performed according to the preferred reporting items for systematic review and meta-analysis (PRISMA) statement [12]. The review protocol was registered in Prospective Registration of Systematic Review (PROSPERO) - CRD42023485950.

Selection criteria

The focused research question of the review was “Is there any difference in the relapse after fixed orthodontic treatment in patients treated with extraction and without extraction?" The framework behind the research question included patients with malocclusion as the population (P), fixed orthodontic treatment with extraction (I), fixed orthodontic treatment without extraction (C), and relapse as the outcome (O). Randomized and non-randomized clinical trials, observational studies, cross-sectional studies, cohort studies, and retrospective studies were included in the review, whereas case reports/series, animal studies, in vitro studies, and review articles were excluded. Studies published since inception up to December 2023 satisfying the above-mentioned PICO framework with full text available in the English language were included for data extraction. The selection of studies was performed through meticulous screening and mutual discussions by authors (PR, SP, SG, and AR). The author PC was consulted for doubts regarding the eligibility of a study. The final selection was based on consensus among all three authors. The corresponding authors of the study were contacted via email when further information was required.

Search strategy

A comprehensive electronic search was performed till December 2023 for relevant studies in the English language using the following databases: PubMed, Google Scholar, EMBASE, and EBSCOhost. Appropriate keywords and Medical Subject Heading (MeSH) terms were selected and combined with Boolean operators like AND. The relevant data was searched using the following keywords and their combinations: “extraction” (MeSH term) AND “orthodontics” (MeSH term) AND “crowding” (MeSH term) “overbite” (MeSH term) AND “overjet” (MeSH term) AND malocclusions (MeSH term). Reference lists of the included articles were screened to identify additional articles missed during the search. Grey literature was identified using Google Scholar, Greylist, and OpenGrey.

Data extraction

The data extraction process was carried out systematically to ensure accuracy and consistency across all included studies. A standardized data extraction form was developed to collect relevant information, including study characteristics (author, year, study design, sample size, age group, and gender distribution), intervention details (extraction versus non-extraction groups, type of extractions performed, follow-up duration), and outcome measures (overjet, overbite, and Little's Irregularity Index). Two independent reviewers (PR and AR) extracted data from each eligible study, with discrepancies resolved through discussion or consultation with a third reviewer (SP). Key metrics, such as mean differences and standard deviations, were recorded for both treatment groups. In cases of missing data, the corresponding authors of the respective articles were contacted through e-mail. Additionally, statistical methods used in each study were documented to facilitate further analysis. The extracted data were then synthesized for meta-analysis, ensuring uniformity in reporting and minimizing the risk of bias during data collection.

Assessment of risk of bias, heterogeneity, and quality of evidence

The methodological quality among included studies was executed by using the ROBINS-I tool [13]. The tool comprises seven domains relevant to various types of biases and an overall rating of low, moderate, or high depending on the scores assigned to the individual domains. The significance of any discrepancies in the estimates of the treatment effects of the different trials was assessed by means of Cochran's test for heterogeneity and the I^2 statistics. For a value of 0% to 40%, the heterogeneity was considered low; 30 to 60% was considered moderate; 50 to 75% was considered substantial, and greater than 75% was considered high heterogeneity. The certainty of the evidence across all the articles included in the present systematic review was assessed using the GRADE approach [14].

Statistical analysis

The standardized mean difference (SDM) with 95% CI was calculated for continuous outcomes. A fixed effects model (Mantel-Haenszel method) was used if there was no heterogeneity ($p > 0.05$ or I-squared ⩽24%); otherwise, a random effects model (Der Simonian-Laird method) was used. All statistical analyses were performed using the RevMan 5.3 (Cochrane Collaboration, Software Update, Oxford, UK). The significance level was kept at $p<0.05$. To test for the presence of publication bias, the relative symmetry of the individual study estimates was assessed around the overall estimates using Begg's funnel plot. A funnel plot (plot of the effect size versus standard error) was drawn.

Study selection

A total of 328 records were identified through database searching. After duplicate removal, the reference list of included studies (n=265) was screened, and 85 studies were excluded. Full-text articles (n=60) were assessed for eligibility, and studies that did not match our inclusion criteria were excluded. Only 10 studies fulfilled eligibility criteria and were included in qualitative synthesis and six studies in meta-analysis [15-24]. A flowchart of identification, inclusion, and exclusion of studies is shown in Figure *1*.

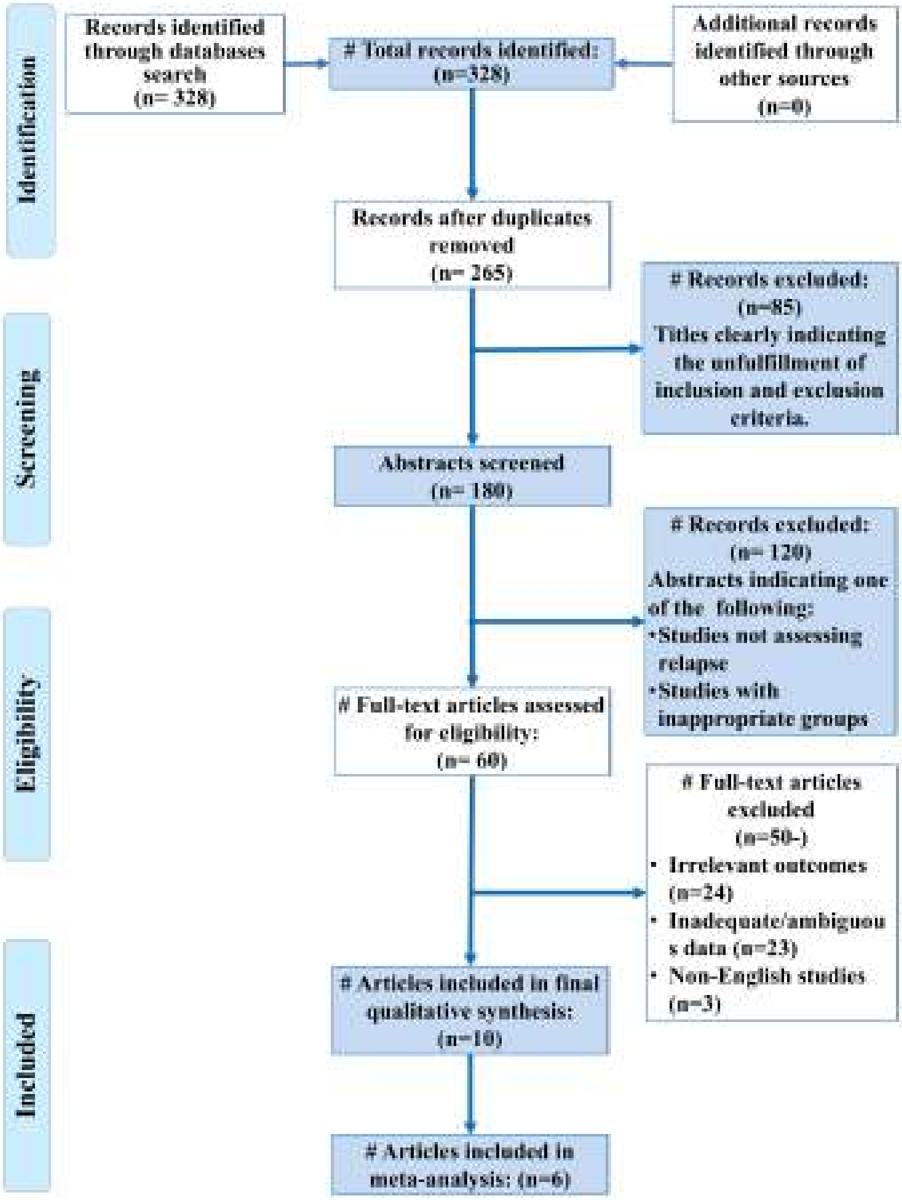

FIGURE 1: PRISMA flow diagram indicating the selection process of the articles in the present systematic review

PRISMA, preferred reporting items for systematic review and meta-analysis

Results of the systematic review

A total of 10 studies were included in this systematic review, comprising a diverse range of study designs, including retrospective, longitudinal, and cross-sectional studies. The data extracted from these studies is comprehensively tabulated in Table *1*. The sample sizes across the studies ranged from 40 to 120 participants, with age groups spanning from 10 to 38 years. The gender distribution across studies showed a predominance of female participants in most studies, with male-to-female ratios varying across the cohorts.

Author (Year)	Study Design	Sample Size	Age Group (years)	Gender (M/F)	Extraction (N)	Non-extraction (N)	Extraction Details	Follow-Up (Years)	Outcome Measures	Key Metrics	Results (Summary)	Statistical Methods
									Overjet, overbite, mandibular	Overjet relapse: 1.0 mm	No significant difference	ANOVA with

Hellekant et al. (1989) [15]	Retrospective study	40	Not stated	15/25	20	20	-	2	intercanine width, maxillary incisor inclination	(NE) vs. 1.4 mm (E); Overbite relapse: 0.8 mm (NE) vs. 1.2 mm (E)	in overjet and overbite relapse between groups	repeated measures
Bishara et al. (1994) [16]	Longitudinal study	91	13-18	41/50	45	46	Maxillary first premolars extracted	5	Overjet, overbite, incisor irregularity, arch length	Overjet relapse: 2.0±0.8 mm (E) vs. 2.7±1.1 mm (NE)	Greater incisor irregularity relapse in non-extraction group	Multivariate Analysis, ANOVA
Rossouw et al. (1999) [17]	Longitudinal study	88	10.1-33.5	33/55	39	49	Premolar extractions	6.8	Overjet, overbite, incisor irregularity, arch length, intercanine width, facial height ratios	Lower incisor irregularity: T1-5.1 mm (E) vs. 2.7 mm (NE); T3-1.7 mm (E) vs. 1.7 mm (NE)	No significant post-treatment differences between groups	Wilcoxon, Chi-square, Spearman correlation
Erdinc et al. (2006) [18]	Longitudinal study	98	T1: 12.0±1.5, T2: 14.6±1.8, T3: 20.6±3.2	48/50	49	49	Premolar extractions	6	Irregularity index, intercanine width, arch depth, overbite, overjet	Incisor irregularity relapse: 0.97 mm (E) vs. 0.99 mm (NE)	No significant differences in relapse patterns between groups	Statistical correlation tests
Janson et al. (2012) [19]	Retrospective study	60	Group 1: 12.14 (9.08-15.55), Group 2: 12.87 (10.90-16.62)	31/29	30	30	Maxillary first premolar extractions	Group 1: 7.15 (2.40-15.53), Group 2: 9.25 (3.18-15.32)	Overjet, overbite, molar & canine relationship	Overjet relapse: 0.37 mm (Group 1) vs. 0.55 mm (Group 2); Overbite relapse: 0.98 mm (Group 1) vs. 1.04 mm (Group 2)	No significant difference in stability between extraction and non-extraction	Student t-test, Pearson correlation
Zafarmand et al. (2014) [20]	Retrospective study	40	Non-extraction: 16.3 (T1), 18.9 (T2), 24.7 (T3); Extraction: 14.9 (T1), 17.8 (T2), 24.6 (T3)	Oct-30	21	19	Upper and lower first premolars	6	Mandibular incisor irregularity index	Initial crowding: 7.23 mm (E) vs. 6.13 mm (NE); post-retention crowding: 2.11 mm (E) vs. 1.65 mm (NE)	No statistically significant difference in relapse between groups (P=0.138)	Wilcoxon test, Mann-Whitney test, Friedman test
Francisconi et al. (2014) [21]	Retrospective study	84	Non-extraction: 12.96 (T1), 15.12 (T2), 20.37 (T3); Extraction: 13.01 (T1), 15.16 (T2), 20.61 (T3)	32/52	40	44	Four first premolars extracted	5	Overjet, overbite, maxillary, mandibular incisor crowding	Initial mandibular irregularity: 5.93 mm (NE) vs. 8.06 mm (E); maxillary irregularity relapse: 1.64 mm (NE) vs. 0.89 mm (E)	Greater maxillary crowding relapse in NE group; greater overbite relapse in E group	T-tests, Pearson correlation, chi-square test
Gorucu-Coskuner et al. (2017) [22]	Retrospective study	44	Mean: 13.6 (SD: 3.07)	19/25	15	16	Four first premolar extractions	43.8	Little's Irregularity Index, intercanine width, interpremolar width, Intermolar width, arch length, arch depth,	Irregularity index relapse: extraction (1.96 mm), anterior repositioning splint (ARS) (2.38 mm), non-extraction (3.59 mm); intercanine width decreased in all groups; arch length and depth decreased significantly in extraction	Significant relapse in all groups, highest in non-extraction group; intercanine width decreased significantly in all groups; lower incisors retroclined in extraction group and proclined in ARS and non-extraction	ANOVA, Welch test, repeated measure ANOVA, least significant difference (LSD) post-hoc test, Levene variance homogeneity

									cephalometric parameters	group	groups	test
Mahmoudzadeh et al. (2018) [23]	Cross-sectional study	120 (40/group)	15-38 (mean 23.1)	21/99	40	40	Single incisor, premolar extractions, and non-extraction	3.5	Incisor irregularity index, overjet, overbite, arch length, intermolar width, intercanine width	Irregularity index: 0.37±0.31 (non-extraction), 0.37±0.41 (premolar extraction), 0.51±0.47 (incisor extraction)	No significant difference among groups (P=0.2); relapse observed in all groups, significant overjet changes in incisor extraction group	ANOVA, Tukey post hoc, Pearson correlation
Bhupali et al. (2019) [24]	Retrospective cohort study	55	Mean: 15.28	20/35	30	25	Four premolar extractions	3 years	Little's Irregularity Index, intercanine width, ABO (affective, behavioral, and cognitive) Model Grading System	Maxillary incisor irregularity decreased from T0-T1 and increased from T1-T2 (P<0.01); mandibular intercanine width increased at T1 but slightly relapsed at T2	No significant differences in relapse between extraction and non-extraction groups (P>0.05); significant relapse in interproximal contacts (P<0.01)	Mann-Whitney U-test, paired t-test, Wilcoxon signed-rank test

TABLE 1: Data extracted from the articles included in the present systematic review

E, extraction; NE, non-extraction

Comparison of extraction versus non-extraction treatments

The included studies assessed the stability of orthodontic treatment outcomes in extraction and non-extraction groups using various outcome measures such as overjet, overbite, incisor irregularity index, intercanine width, arch length, and intermolar width. The studies provided mixed results regarding the impact of extraction on post-treatment stability.

Overjet and Overbite Relapse

Francisconi et al. (2014) reported greater overbite relapse in the extraction group compared to the non-extraction group [21]. Similarly, Hellekant et al. (1989) and Bishara et al. (1994) found no significant differences in overjet relapse between the two groups [15,16]. In contrast, Mahmoudzadeh et al. (2018) reported significant overjet relapse in the incisor extraction group, indicating that extraction of incisors may contribute to greater overjet relapse [23].

Incisor Irregularity Index

Most studies, including Erdinc et al. (2006) and Rossouw et al. (1999), observed no significant differences in incisor irregularity relapse between extraction and non-extraction treatments [17,18]. However, Mahmoudzadeh et al. (2018) and Zafarmand et al. (2014) indicated that mandibular crowding relapse was more pronounced in the non-extraction group compared to extraction-treated individuals [20,23].

Intercanine Width and Arch Length

Studies such as Gorucu-Coskuner et al. (2017) highlighted a significant decrease in intercanine width in all groups, with the highest decrease in the extraction group [22]. Bhupali et al. (2019) also reported a decrease in maxillary arch length post-retention, with similar patterns observed across both groups [24]. A key observation across multiple studies was the tendency of the non-extraction group to exhibit greater arch length reduction, leading to relapse over time.

Follow-up duration and retention protocols

The follow-up periods ranged from two to seven years across studies, with standardized retention protocols commonly involving the use of Hawley or bonded retainers. Studies such as Janson et al. (2012) and Francisconi et al. (2014) indicated that retention protocols significantly influenced post-treatment stability [19,21]. The use of fixed mandibular retainers was associated with improved long-term outcomes in both extraction and non-extraction cases.

Statistical analysis and significance

Various statistical methods were employed across studies, including ANOVA, Wilcoxon tests, Pearson correlation, and t-tests. Most studies reported no statistically significant differences in post-treatment relapse patterns between the extraction and non-extraction groups. However, specific differences in maxillary and mandibular crowding relapse were noted in some studies.

Key findings

Extraction treatment appeared to offer better stability in terms of maxillary incisor crowding and overbite control. Non-extraction cases showed higher relapse rates in terms of incisor irregularity and arch length stability. Retention protocols play a critical role in maintaining treatment outcomes, with fixed retainers showing favorable results in preventing relapse. The findings of this systematic review suggest that both extraction and non-extraction treatment modalities can achieve clinically acceptable stability, with no significant differences in long-term relapse patterns. However, individual variability, retention strategies, and treatment planning play a crucial role in determining post-treatment stability.

Assessment of risk of bias of included studies

The studies by Bishara et al. (1994) [16], Rossouw et al. (1999) [17], and Zafarmand et al. (2014) [20] showed a low overall risk of bias, while the remaining studies exhibited a moderate risk, mainly due to confounding factors and participant selection bias (Figure *2*). Retrospective study designs in some cases introduced selection bias, as patients were not randomly allocated, and missing data in studies with longer follow-ups further impacted result reliability. Studies by Hellekant et al. (1989) [15], Janson et al. (2012) [19], Gorucu-Coskuner et al. (2017) [22], Mahmoudzadeh et al. (2018) [23], and Bhupali et al. (2019) [24] had a moderate confounding bias, indicating that factors such as patient compliance and treatment variations could have influenced outcomes. Bias due to missing data was particularly noted in longer follow-up studies, potentially introducing attrition bias. However, the classification of interventions and deviations from intended treatments were consistently low across studies, ensuring well-defined treatment protocols, though subjective assessment methods led to moderate measurement bias in some cases. Overall, while the studies included in this review provide valuable insights into the comparison between extraction and non-extraction treatments, the presence of moderate bias in several domains underscores the need for future research with more standardized methodological approaches, including randomized controlled trials and standardized outcome measures to enhance the reliability of findings.

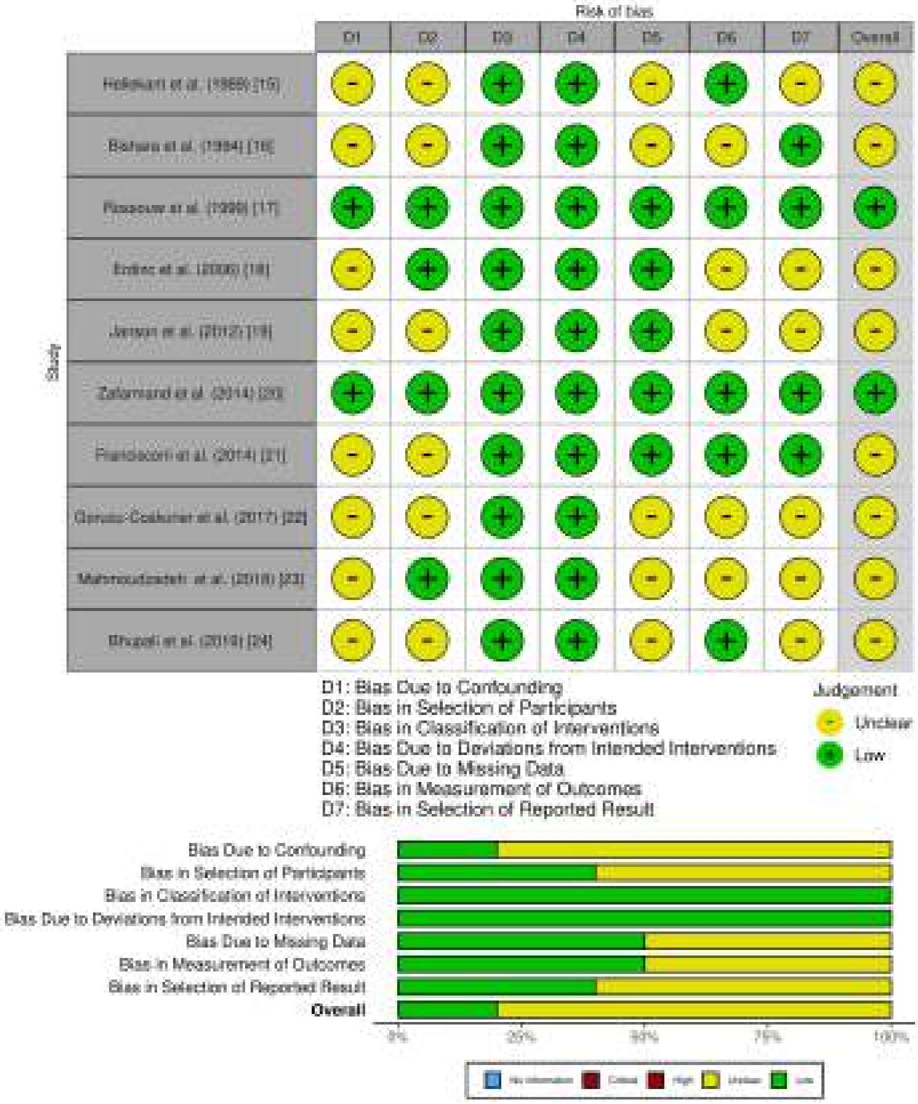

FIGURE 2: Risk of bias according to the reviewers' judgments about each domain across all included studies

Certainty of evidence across the included studies

The rating of various domains when assessing the certainty of evidence across the different articles included in the present systematic review using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) approach is summarized in Table 2.

Author (Year)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality
Hellekant et al. (1989)	Moderate	Not serious	Not serious	Moderate	Uncertain	Moderate
Bishara et al. (1994)	Moderate	Not serious	Not serious	Not serious	Uncertain	Moderate
Rossouw et al. (1999)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Erdinc et al. (2006)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Janson et al. (2012)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Zafarmand et al. (2014)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Francisconi et al. (2014)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Gorucu-Coskuner et al. (2017)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Khosravi et al. (2018)	Not serious	Not serious	Not serious	Not serious	Uncertain	High
Bhupali et al. (2019)	Not serious	Not serious	Not serious	Not serious	Uncertain	High

TABLE 2: Rating the various domains of evidence quality using the GRADE approach

GRADE, Grading of Recommendations, Assessment, Development, and Evaluation

The body of evidence supporting the comparison between extraction and non-extraction treatment outcomes is largely robust, with most studies demonstrating high-quality evidence based on the GRADE criteria. In particular, the more recent investigations by Rossouw et al. (1999), Erdinc et al. (2006), Janson et al. (2012), Zafarmand et al. (2014), Francisconi et al. (2014), Gorucu-Coskuner et al. (2017), Khosravi et al. (2018), and Bhupali et al. (2019) exhibit minimal concerns regarding risk of bias, inconsistency, indirectness, and imprecision. These studies provide consistent and precise estimates that directly address the clinical question of post-treatment relapse, reflecting improved study designs and methodological rigor. Although publication bias remains uncertain, the strength and consistency of the findings from these later studies underpin a high level of confidence in the overall evidence.

In contrast, earlier studies such as Hellekant et al. (1989) and Bishara et al. (1994) are rated as moderate quality due to modest concerns regarding risk of bias and imprecision, limitations that are likely related to smaller sample sizes and less rigorous control of confounding factors. Despite these limitations, the contributions of Hellekant et al. (1989) and Bishara et al. (1994) remain valuable in providing historical context and broadening the overall evidence base. Taken together, while acknowledging the moderate quality of the earliest evidence, the cumulative findings from the systematic review indicate that the more recent research offers robust and reliable data to inform clinical decision-making regarding extraction versus non-extraction treatment protocols.

Synthesis of results

The meta-analysis was conducted with an SMD as a summary statistic measure for comparison between extraction and non-extraction groups to assess the outcomes in terms of overjet, overbite, and Little's Irregularity Index.

Overjet

Three studies contained data on 219 participants, of which 110 participants were evaluated by extraction and 109 patients were evaluated by non-extraction for the evaluation in terms of overjet [21,23,24]. As shown in Figure *3*, the SMD is 0.52 (-0.18 - 1.23), and the pooled estimates favor the non-extraction group, but this difference is not statistically significant (p>0.05). The funnel plot did not show significant asymmetry, indicating an absence of publication bias.

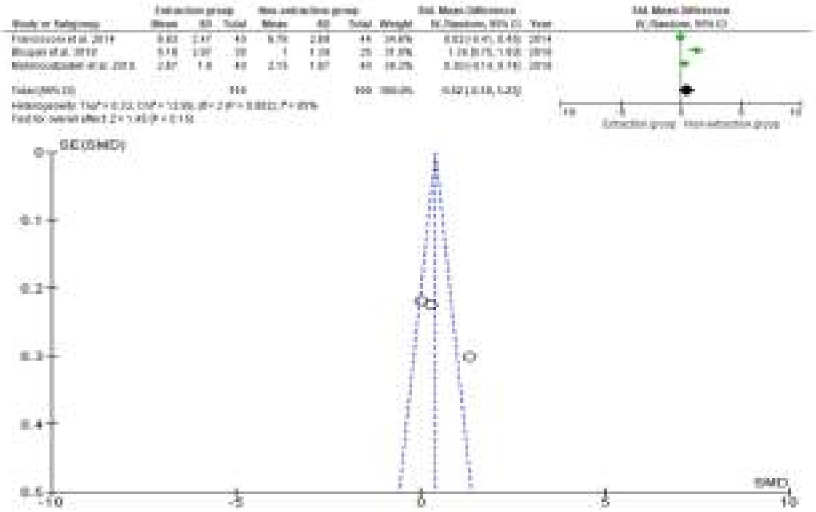

FIGURE 3: Comparison of overjet relapse between the extraction and non-extraction groups and publication bias, indicated by Begg's funnel plot with 95% CI

SMD, standardized mean difference

Overbite

Three studies with data on 216 participants were included, of which 111 participants were evaluated with extraction and 105 participants were evaluated with non-extraction for the assessment of overbite [19,21,23]. As shown in Figure *4*, the SMD is 0.41 (-0.11 to 0.93), and the pooled estimates favor the non-extraction group, but this difference is not statistically significant (p>0.05). The funnel plot did not show significant asymmetry, indicating an absence of publication bias.

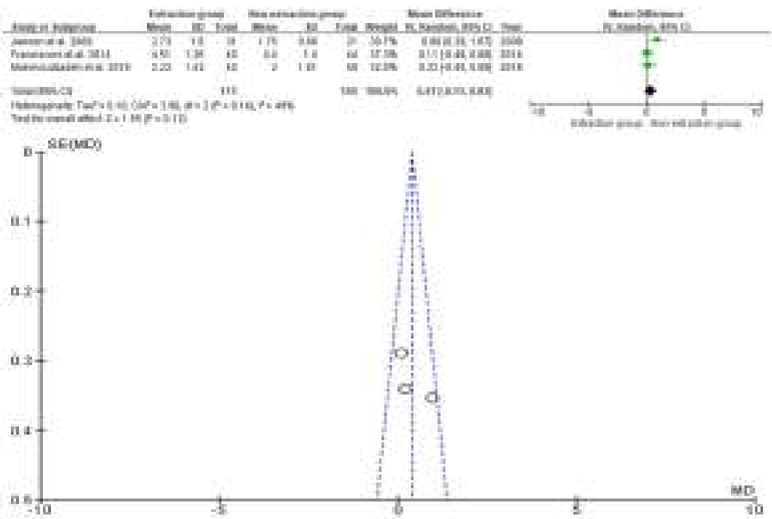

FIGURE 4: Comparison of overbite relapse between the extraction and non-extraction groups and publication bias, as indicated by Begg’s funnel plot with a 95% CI

Little’s Irregularity Index

Three studies with data on 199 participants were included, of which 121 participants were evaluated with extraction and 78 participants were evaluated with non-extraction for the assessment of the Little's Irregularity Index. As shown in Figure *5* [17,21,22], the SMD is 0.71 (-0.01 to 1.23), and the pooled estimates favor the non-extraction group. This suggests that, on average, overjet is 0.52 times greater in the non-extraction group compared to the extraction group, but this difference is not statistically significant ($p>0.05$). The funnel plot did not show significant asymmetry, indicating an absence of publication bias.

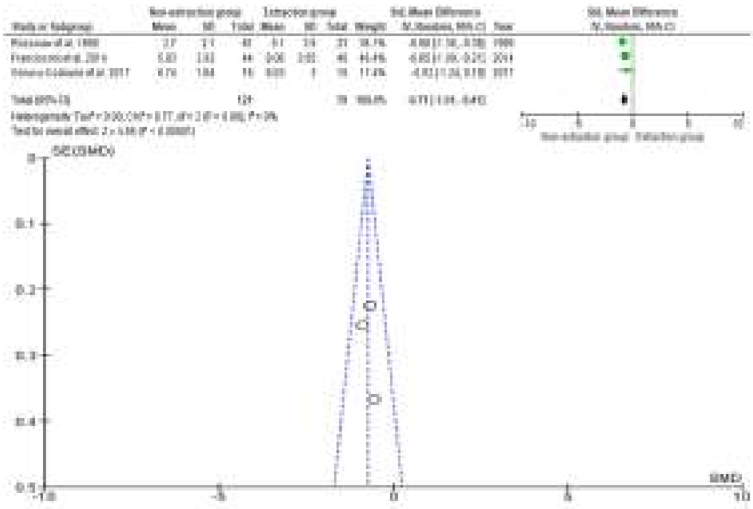

FIGURE 5: Comparison of Little's Irregularity Index between the extraction and non-extraction groups and publication bias, as indicated by Begg's funnel plot with a 95% CI

Discussion

The results of this systematic review and meta-analysis suggest that both extraction and non-extraction orthodontic treatments achieve comparable long-term stability in terms of overjet, overbite, and incisor irregularity. Although the pooled estimates for overjet and overbite relapse favored the non-extraction group, the differences were not statistically significant, indicating that both treatment approaches can provide satisfactory outcomes with appropriate retention protocols. The slight advantage observed in the non-extraction group could be attributed to the preservation of arch length and the avoidance of potential biomechanical effects associated with space closure in extraction cases. However, the clinical significance of these differences remains uncertain, and the decision between extraction and non-extraction should be based on individual patient needs and occlusal considerations.

The findings related to Little's Irregularity Index indicate a trend of higher relapse rates in the non-extraction group, which aligns with the understanding that untreated crowding has a greater tendency to relapse over time. Non-extraction treatments often rely on transverse expansion and incisor proclination to achieve alignment, both of which can contribute to long-term instability due to soft tissue pressures and natural aging processes [25,26]. In contrast, extraction cases provide space for proper tooth alignment and allow for more stable arch form maintenance, which may explain the relatively lower irregularity index relapse observed in those cases. This highlights the importance of meticulous space management and long-term follow-up in non-extraction treatments to prevent potential relapse.

Despite the absence of significant publication bias in the included studies, some degree of heterogeneity was noted across the studies in terms of sample size, follow-up duration, and retention strategies. These variations could influence the reported outcomes and should be considered when interpreting the findings. Factors such as patient compliance with retention protocols, biological variability in response to treatment, and differences in orthodontic mechanics employed may have contributed to the observed inconsistencies [27,28]. Future studies with standardized retention protocols and longer follow-up durations are warranted to provide more conclusive evidence regarding treatment stability.

From a clinical perspective, the findings underscore the importance of individualized treatment planning that considers not only the initial malocclusion but also long-term stability factors such as arch form preservation, periodontal health, and patient compliance. While non-extraction treatment may be preferable in cases where facial profile and soft tissue harmony are a primary concern, extraction therapy should not be overlooked when space management is critical to achieving stable occlusion. Additionally, retention strategies should be customized based on the treatment modality, with non-extraction patients potentially requiring more prolonged retention to mitigate relapse risks.

The limitations of the included studies, such as retrospective designs and varying assessment methods, highlight the need for future prospective randomized controlled trials to provide stronger evidence on the long-term outcomes of extraction versus non-extraction treatments. Additionally, the role of adjunctive measures such as interproximal reduction and fixed retainers in enhancing stability should be explored to further optimize post-treatment outcomes. Overall, while the studies included in this review provide valuable insights into the comparison between extraction and non-extraction treatments, the presence of moderate bias in several domains reinforces the need for future research with more standardized methodological approaches. There is a particular need for conducting randomized controlled trials and standardized outcome measures to enhance the reliability of findings. While both treatment modalities can achieve satisfactory long-term stability, careful patient selection and adherence to retention protocols are crucial to maintaining treatment outcomes and minimizing relapse risks.

Conclusions

The findings of this systematic review and meta-analysis suggest that there is no statistically significant difference in the relapse of overjet, overbite, and Little's Irregularity Index between extraction and non-extraction treatment modalities. Although the pooled estimates favor the non-extraction group in all evaluated parameters, the differences observed were not clinically significant, indicating that both treatment approaches can achieve comparable long-term stability. The variability in relapse outcomes across studies highlights the influence of individual patient factors, treatment techniques, and retention protocols on orthodontic stability. Despite the moderate risk of bias in several included studies, the overall evidence suggests that clinicians should focus on individualized treatment planning based on patient-specific needs rather than a generalized preference for extraction or non-extraction. Future well-designed longitudinal studies with standardized outcome measures and longer follow-up periods are necessary to further validate these findings and provide more definitive clinical recommendations.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Supervision: Priya Rajput, Suryakant Powar, Sumeet Ghonmode

Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Iared W, Koga da Silva EM, Iared W, Rufino Macedo C: Esthetic perception of changes in facial profile resulting from orthodontic treatment with extraction of premolars: a systematic review. J Am Dent Assoc. 2017, 148:9-16. 10.1016/j.adaj.2016.09.004
2. Chacón-Moreno A, Ramírez-Mejía MJ, Zorrilla-Mattos AC: Relapse and inadvertent tooth movement post orthodontic treatment in individuals with fixed retainers: a review. Rev Cient Odontol (Lima). 2022, 10:e116. 10.21142/2523-2754-1003-2022-116
3. Janson G, Junqueira CH, Mendes LM, Garib DG: Influence of premolar extractions on long-term adult facial aesthetics and apparent age. Eur J Orthod. 2016, 38:272-80. 10.1093/ejo/cjv039
4. Najjar HE, Alasmari RM, Al Manie AM, et al.: Factors affecting retention and relapse in orthodontics . Int J Com Med Pub Health. 2023, 10:1-5. 10.18203/2394-6040.ijcmph20232173
5. Aurellia SC, Dermawan TM, Akifah TF, Pakpahan EL: Relapse after orthodontic treatment. Moestopo Int Rev Soc Human Sci. 2024, 4:238-50. 10.32509/mirshus.v4i2.97
6. De Praeter J, Dermaut L, Martens G, Kuijpers-Jagtman AM: Long-term stability of the leveling of the curve of Spee. Am J Orthod Dentofacial Orthop. 2002, 121:266-72. 10.1067/mod.2002.121009
7. Al-Buraiki H, Sadowsky C, Schneider B: The effectiveness and long-term stability of overbite correction with

incisor intrusion mechanics. Am J Orthod Dentofacial Orthop. 2005, 127:47-55. 10.1016/j.ajodo.2003.10.034
8. Alsaggaf DH, Afify AR, Zawawi KH, Alsulaimani FF: Factors influencing the orthodontic treatment plan in class II malocclusion. Am J Orthod Dentofacial Orthop. 2022, 161:829-37.e1. 10.1016/j.ajodo.2021.01.034
9. Kiyamehr Z, Razeghinejad MH, Rahbar M, Oskouei SG, Vafaei A: Factors affecting the duration of fixed orthodontic treatment in patients treated in a university department between 2016 and 2020. Maedica (Bucur). 2022, 17:380-6.
10. Moher D, Liberati A, Tetzlaff J, Altman DG: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009, 6:e1000097. 10.1371/journal.pmed.1000097
11. Corbett MS, Higgins JP, Woolacott NF: Assessing baseline imbalance in randomised trials: implications for the Cochrane risk of bias tool. Res Synth Methods. 2014, 5:79-85. 10.1002/jrsm.1090
12. Higgins JP, Thompson SG: Quantifying heterogeneity in a meta-analysis. Stat Med. 2002, 21:1539-58. 10.1002/sim.1186
13. Sterne JA, Becker BJ, Egger M: The Funnel Plot. Publication Bias in Meta-Analysis: Prevention, Assessment, and Adjustments. Rothstein HR, Sutton AJ, Borenstein M (ed): PublisherJohn Wiley & Sons, Inc, 2005. 75-98. 10.1002/0470870168.ch5
14. DerSimonian R, Laird N: Meta-analysis in clinical trials revisited. Contemp Clin Trials. 2015, 45:139-45. 10.1016/j.cct.2015.09.002
15. Hellekant M, Lagerström L, Gleerup A: Overbite and overjet correction in a class II, division 1 sample treated with Edgewise therapy. Eur J Orthod. 1989, 11:91-106. 10.1093/oxfordjournals.ejo.a035984
16. Bishara SE, Cummins DM, Zaher AR: Treatment and posttreatment changes in patients with class II, division 1 malocclusion after extraction and nonextraction treatment. Am J Orthod Dentofacial Orthop. 1997, 111:18-27. 10.1016/s0889-5406(97)70297-x
17. Rossouw PE, Preston CB, Lombard C: A longitudinal evaluation of extractionversus nonextraction treatment with special reference to the posttreatment irregularity of the lower incisors. Sem Orthod. 1999, 5:160-70. 10.1016/s1073-8746(99)80007-3
18. Erdinc AE, Nanda RS, Işiksal E: Relapse of anterior crowding in patients treated with extraction and nonextraction of premolars. Am J Orthod Dentofacial Orthop. 2006, 129:775-84. 10.1016/j.ajodo.2006.02.022
19. Janson G, Araki J, Camardella LT: Posttreatment stability in class II nonextraction and maxillary premolar extraction protocols. Orthodontics (Chic.). 2012, 13:12-21.
20. Zafarmand AH, Qamari A, Zafarmand MM: Mandibular incisor re-crowding: is it different in extraction and non-extraction cases?. Oral Health Dent Manag. 2014, 13:669-74.
21. Francisconi MF, Janson G, Freitas KM, Oliveira RC, Oliveira RC, Freitas MR, Henriques JF: Overjet, overbite, and anterior crowding relapses in extraction and nonextraction patients, and their correlations. Am J Orthod Dentofacial Orthop. 2014, 146:67-72. 10.1016/j.ajodo.2014.04.012
22. Gorucu-Coskuner H, Atik E, Kocadereli I: Effects of three different orthodontic treatment methods on the stability of mandibular incisor alignment. J Clin Pediatr Dent. 2017, 41:486-93. 10.17796/1053-4628-41.6.13
23. Mahmoudzadeh M, Mirzaei H, Farhadian M, Mollabashi V, Khosravi M: Comparison of anterior crowding relapse tendency in patients treated with incisor extraction, premolar extraction, and nonextraction treatment. J World Fed Orthod. 2018, 7:61-5. 10.1016/j.ejwf.2018.03.002
24. Bhupali NR, Singh SP, Verma S, Kumar V, Verma RK: Long term stability of treatment outcome after fixed orthodontic treatment with or without premolar extraction. Orthod Waves. 2019, 78:26-32. 10.1016/j.odw.2018.12.001
25. Hajrasi MK, Al-Fraidi AA, Hatrom AA, Hassan AH: Nonextraction management of severely malaligned and constricted upper arch. Case Rep Dent. 2020, 2020:8836061. 10.1155/2020/8836061
26. Chikankar T, Kaiser J, Gupta K, Kamble R: Non-extraction approach in a borderline case of a growing patient: a case report. Cureus. 2024, 16:e62195. 10.7759/cureus.62195
27. Fu LM, Ellman S, Gao J, Tahir P, Oberoi S: Patient compliance with removable orthodontic retainers during retention phase: a systematic review. J Calif Dent Assoc. 2023, 51:2243016. 10.1080/19424396.2023.2243016
28. Alikhani M, Chou MY, Khoo E, et al.: Age-dependent biologic response to orthodontic forces. Am J Orthod Dentofacial Orthop. 2018, 153:632-44. 10.1016/j.ajodo.2017.09.016

ORIGINAL RESEARCH PAPER

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ASSESSMENT OF THE KNOWLEDGE, ATTITUDE AND PRACTICE REGARDING STERILIZATION AND DISINFECTION OF IMPRESSION TRAYS AMONG UNDERGRADUATES, INTERNS, POSTGRADUATES: A QUESTIONNAIRE-BASED STUDY

Dentistry

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ABSTRACT

Conventional impression techniques are the primary method taught for taking impressions in most dental institutes. Although digital impression techniques have emerged, their adoption in countries like India remains limited due to the high cost of equipment and socioeconomic factors. As a result, conventional impressions continue to be widely used. However, these impressions can harbor microbes and pose a significant risk of infection. Therefore, it is essential to adhere to proper sterilization protocols to disinfect impression trays before reuse. Various studies indicate a significant lack of awareness among students in various dental institutes. This study aims to address this knowledge gap in undergraduates, interns, and postgraduates on sterilization and disinfection practices for impression trays, while also establishing a scientific basis for these protocols

KEYWORDS

sterilization, impression, disinfection, infection

INTRODUCTION –

In today's era, digital impressions have become a significant method for making dental impressions[1]. However, in a country like India, several factors such as the high cost of hardware, expensive training programs, and the socioeconomic background of the population have hindered the widespread adoption of digital impressions. As a result, conventional impression techniques are still primarily taught as the basic method in most dental institutions. This, however, exposes students to potential contamination from patients' saliva[2]. To mitigate this risk, it is crucial to follow proper sterilization protocols to disinfect impression trays before reusing them. Therefore, dental institutions must educate students on the various sterilization methods for impression trays to ensure safe and effective practice.

Dental professionals take impressions daily, which exposes them to blood, saliva, and other potentially infectious materials. On an average, 1 ml of saliva contains around 750 million microbes[3]. This puts dental professionals at a higher risk of contacting infectious diseases such as AIDS, herpes, hepatitis, and tuberculosis[4]. Additionally, the risk of cross-contamination is increased if proper sterilization protocols for impression trays are not followed.

Various authoritative organizations[5,6], manufacturers[7], academic researchers[8,9], and textbooks on dental materials[10-14] consistently propose diverse guidelines for sterilization and disinfection procedures.

Impression trays are considered semi-critical items. According to CDC guidelines[5], if impression trays are sterilized without being wrapped, they should be used immediately. The ADA guidelines[6] recommend that when instruments need to be stored after sterilization, they should be wrapped in materials such as muslin, clear pouches, or paper, following the manufacturer's specifications.

Studies have shown that perforated impression trays harbour higher levels of microbial flora compared to other types of trays. Despite this, perforated trays are still commonly used for alginate impressions due to their better retentive properties. Non-disposable plastic impression trays are also considered potential sources of infection[15,16]. Therefore, disposable impression trays and autoclavable metal trays are considered superior for infection control.

It is the responsibility of the dental professionals making impressions, to strictly adhere to proper sterilization and disinfection protocols. Failure to follow these protocols increases the risk of infection for both dental professionals and anyone handling the impressions. Several studies have investigated the knowledge of sterilization practices during impression procedures among dental professionals. These studies reveal a notable lack of awareness within these groups. Consequently, this study aims to bridge the knowledge gap regarding the sterilization and disinfection of impression trays among undergraduates, interns, and postgraduates, while also establishing a scientific foundation for sterilization practices related to impression trays.

MATERIALS AND METHODS –

A validated structured questionnaire containing 16 questions was distributed to undergraduates, interns and postgraduates from various dental institutes in Maharashtra. The questionnaire was divided into three sections: Section 1 focused on knowledge-based questions (Figure2), Section 2 covered practice-related questions (Figure3), and Section 3 addressed attitude-related questions (Figure3).

The study had a sample size of 117. A total of 120 responses were obtained which was sufficient according to the calculated sample size (Figure1)

P	Your guess of Population P (any value<1)	0.57
1-a	Confidence level set by you	0.95
Z	Z value associated with confidence	1.96
d	Absolute precision (Value less than P)	0.09
n	Minimum sample size	117

n=(〖Z1〗 ^2 {P(1-P))/d^2

Figure 1 - SAMPLE SIZE: Estimation of Population Proportion

The study objectives were clearly explained to the participants, and informed consent was obtained from them. The validated questionnaire was distributed through a Google Form shared via WhatsApp to dental undergraduates, interns, and postgraduates from various dental institutions in Maharashtra.

To evaluate their knowledge, all the three groups were asked various questions about the sterilization and disinfection of impression trays. Additionally, these groups were surveyed on the practices they follow for sterilizing impression trays. Finally, their attitudes towards sterilization and disinfection protocols were assessed.

Data collection and analysis were done through Microsoft Excel 2017

Knowledge Related Questions –

Q1. Which Type Of Impression Trays Should You Preferably Use To Take Alginate Impression
- Metal perforated trays
- Plastic trays
- Disposable trays
- Custom made trays

Q2. Should Impression Trays Be Washed Before Impression Making Procedure
- Yes
- No

Q3. What Is The Most Practical Method Of Sterilization Of Metal Impression Trays
- Chemical
- Boiling
- Autoclave

Q4. Most Effective Method Of Sterilization Of Metal Impression Trays
- Boiling
- Autoclave
- Chemical

Q5. Which Among These Is A High-level Disinfectant For Impression Trays
- Glutaraldehyde
- Chlorine
- Sodium hypochlorite
- Iodophors

Q6. Uv Chamber Works As A ………...For Impression Trays
- Sterilizer
- Disinfectant

Q7. Can Custom Made Acrylic Impression Trays Be Autoclaved
- Yes
- No

Q8. What Is The Most Common Method To Check The Sterilization Efficiency Of Autoclave
- Biological
- Chemical
- Physical

Figure 2 – Knowledge related questions

Practice Related Questions –

Pq1. How Often Do You Sterilize Impression Trays During Impression Making Procedure
- Before every patient
- Weekly once
- Monthly once
- Monthly multiple times

Pq2. How Do You Take Impression In Newborn Cleft Patients
- Impression trays
- Finger manipulation using gloves
- None

Pq3. How Do You Proceed With The Sterilization Of The Gloves Which Is Used To Take Impression In Newborn Cleft Patients
- Autoclave
- Using 2 percent Glutaraldehyde solution
- Use pre – sterilized surgical gloves

Pq4. How Do You Disinfect Custom Made Acrylic Impression Trays
- 1:10 sodium hypochlorite
- Autoclave
- Boiling
- None

Pq5. How Do You Sterilize Intraoral Scanner Tips During Digital Impression Making Procedure
- Boiling
- Autoclave
- Wiping with surgical spirit

Pq6. In Case Of Restricted Mouth Opening, How Do You Sterilize Metal Sectional Impression Trays
- Autoclave
- Chemical methods
- Boiling

Attitude Related Questions –

A1. Do You Feel Impression Trays Should Be Sterilized After Every Use
- Yes
- No

A2. Is It Important To Check For Sterilization Efficiency Of Autoclave Monthly Sterilizing Impression Trays
- Yes
- No

Figure 3 – Practise and attitude related questions

Statistical Analysis

Data was collected and compiled on to MS office excel worksheet and was subjected to statistical analysis using an appropriate package like SPSS software version 25 for Windows (SPSS Inc, Chicago, IL). Data normality was checked by using Shapiro-Wilk test. Quantitative data was expressed in mean and standard deviation respectively. Intergroup comparison of parameters between the 3 groups was done using One Way ANOVA Test. Keeping alpha error at 5%, and Beta error at 20%, Power at 80% $p \leq 0.05$* was considered statistically significant.

RESULTS

A total of 120 responses were collected via Google Sheets. Knowledge-related questions are presented in Figure 2, while practice and attitude related questions are detailed in Figure 3. Regarding the type of impression trays preferred for alginate impressions, the majority of postgraduates, interns, and undergraduates concurred that metal perforated impression trays are the preferred choice. No statistically significant differences were observed among the three groups (Image 1).

Only a small number of participants across all the three groups agreed that impression trays should not be washed before making impressions, whereas the majority reported washing their impression trays prior to use (Image 2).

The majority of postgraduates (n=44) agreed that autoclaving is the most effective method for sterilizing impression trays. A statistically significant difference was observed among the three groups (Image 4).

When asked about the use of high-level disinfectants for impression trays, many postgraduates indicated a preference for sodium hypochlorite. A statistically significant difference was observed among the groups (Image 5).

A significant number of interns (n=36) and postgraduates(n=44) agreed that UV chamber works as a disinfectant rather than a steriliser for impression trays (Image 6)

Many postgraduates agreed that custom made acrylic impression trays can be sterilised, and the result was statistically significant (Image 7). When questioned about the disinfection of custom-made impression trays, more than half of the postgraduates practised the disinfection using sodium hypochlorite (Image 12).

A larger number of postgraduates, compared to undergraduates and interns, reported wiping the intraoral scanner tips before taking digital impressions, with the result being statistically significant (Image 13). The vast majority of participants across all the three groups agreed that it is important to check the sterilization efficacy of the autoclave on a monthly basis (Image 16).

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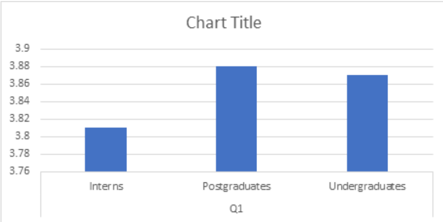

Image 1 – Mean value comparison between undergraduates, interns and postgraduates for Q1. p value- 0.66

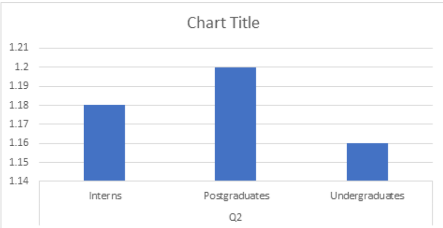

Image 2– Mean value comparison between undergraduates, interns and postgraduates for Q2. p value-0.93

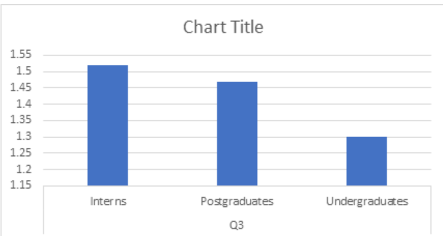

Image 3– Mean value comparison between undergraduates, interns and postgraduates for Q3. p value-0.36

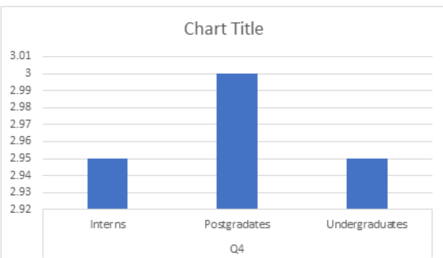

Image 4– Mean value comparison between undergraduates, interns and postgraduates for Q4. p value-0.65

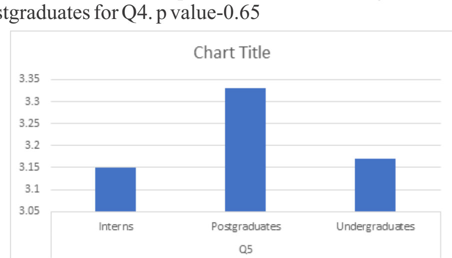

Image 5– Mean value comparison between undergraduates, interns and postgraduates for Q5. p value-0.04*

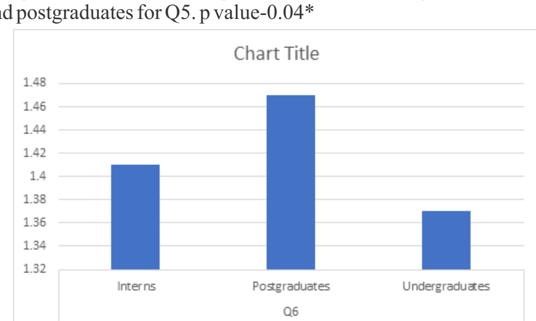

Image 6– mean value comparison between undergraduates, interns and postgraduates for Q6. p value-0.64

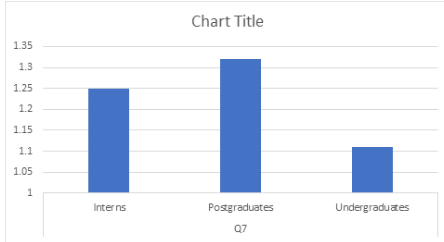

Image 7– mean value comparison between undergraduates, interns and postgraduates for Q7. p value-0.05*

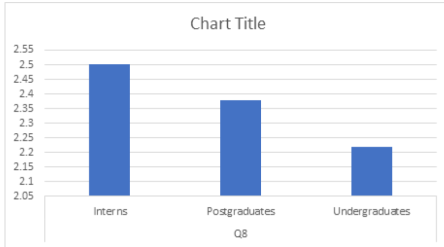

Image 8– Mean value comparison between undergraduates, interns and postgraduates for Q8. p value-0.32

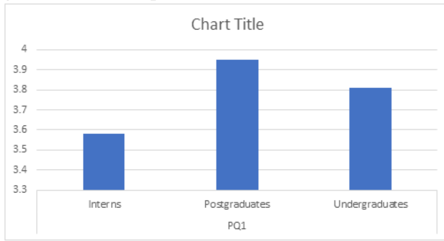

Image 9– mean value comparison between undergraduates, interns and postgraduates for PQ1. p value-0.02*

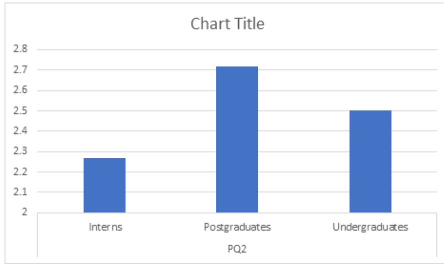

Image 10– mean value comparison between undergraduates, interns and postgraduates for PQ2. p value-0.03*

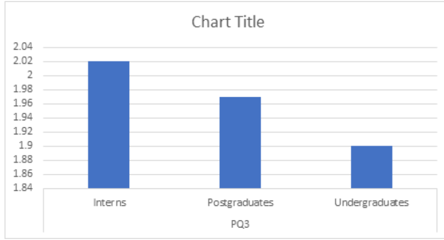

Image 11– mean value comparison between undergraduates, interns and postgraduates for PQ3. p value-0.57

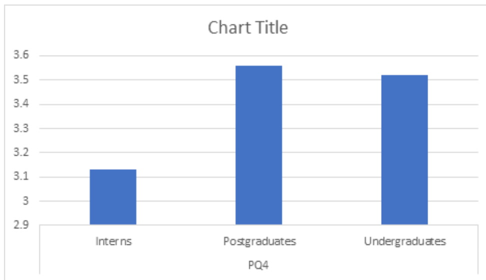

Image 12– mean value comparison between undergraduates, interns and postgraduates for PQ4. p value-0.01*

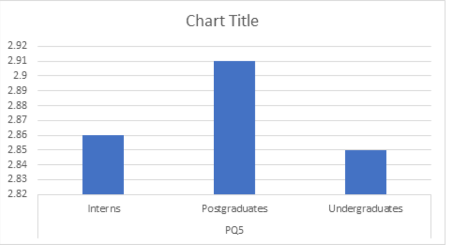

Image 13– mean value comparison between undergraduates, interns and postgraduates for PQ5. p value-0.05*

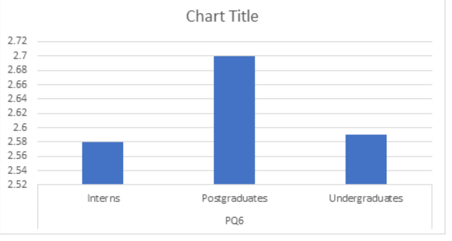

Image 14– mean value comparison between undergraduates, interns and postgraduates for PQ6. p value-0.63

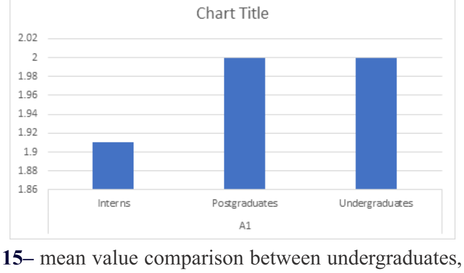

Image 15– mean value comparison between undergraduates, interns and postgraduates for A1. p value-0.02*

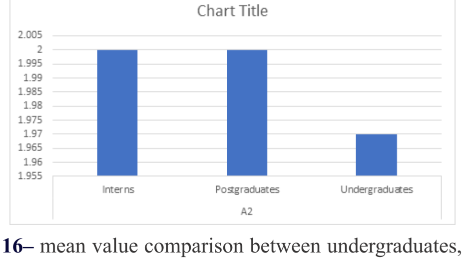

Image 16– mean value comparison between undergraduates, interns and postgraduates for A2. p value-0.42

DISCUSSION

Impression making procedures are a routine part of dental practice, used to record the teeth and surrounding anatomical structures. Impression trays, which are commonly used, are a significant source of infection, as they become contaminated with saliva. Various infections, including Hepatitis B, HIV, and Mycobacterium tuberculosis, can be transmitted from one individual to another [17,18]. Therefore, it is essential that all materials used in impression procedures, including the impression trays, be thoroughly disinfected and sterilized.

Metallic perforated impression trays are the preferred choice for making alginate impressions due to their ability to securely interlock the alginate within the perforations, resulting in accurate impressions. The present study indicates that undergraduates, interns, and postgraduates recognize the preference for metallic perforated trays for this purpose. A study by Asad et al.[19] found that 66.7% of the study group supported using metallic impression trays to reduce the risk of cross-contamination which is similar to the results of our study.

After the sterilisation of impression trays, they should directly be used to take impression without rinsing with water. A study by Amin et al.[20] highlights that washing sterilized impression trays before use can lead to contamination. A study conducted by Rubab Jawed et al.[21] shows that 50% percent of participants washed impression trays before impression making, while a study conducted by Ukuoghene et al [22] concluded that 100% of the participants washed their trays. This is an important consideration for professionals involved in making impressions. However, participants in our study demonstrated a lack of awareness on this issue, with the majority of them washing their impression trays before use.

Autoclave is widely regarded as the most effective sterilization method for metallic impression trays [23]. It operates at 121°C or higher for 15 to 20 minutes and can also operate at 115°C/10 psi, 121°C/15 psi, and 134°C/30 psi. The efficacy of autoclave sterilization can be verified through biological, chemical and physical methods, with biological indicators being the most common. These indicators typically use spores of Bacillus stearothermophilus as a standard marker of sterilization effectiveness [24]. Majority of the postgraduates in our study responded for autoclave as the most effective method of sterilisation of impression trays. Most of the interns and postgraduates also felt that, it is important to check the sterilisation efficacy of Autoclave on a monthly basis.

Chemical methods are among the most practical approaches for disinfection, with sodium hypochlorite being considered a high-level disinfectant. The contact period of chemicals with trays should be approximately 12-15 minutes for its disinfectant action. Sodium hypochlorite (HOCl) penetrates microbial cells, inhibiting enzyme activity, damage the cell membrane and DNA, and impair membrane transport capacity [25]. In our study, more than half of the postgraduates were aware of sodium hypochlorite's role as a high-level disinfectant, aligning with findings from a study conducted by Jain et al.[2]

Ultraviolet (UV) radiation is a type of electromagnetic radiation with wavelengths ranging from 100 to 400 nm, categorized into UVA, UVB, and UVC. Among these, UVC is the most effective one [26]. UV chambers works as a disinfectant for impression trays, as UV rays effectively eliminate microbes without the use of chemicals or heat. Many interns and postgraduates in our study are well aware about the disinfectant role of UV chamber.

Intraoral scanner tips are utilized for recording digital impressions, which helps to reduce chairside time of making conventional impression[1]. Digital impressions provide a high degree of accuracy in impression-making techniques and allows a seamless transfer of images from the dental clinic to the dental laboratory for evaluation[27,28]. In our study, majority of the postgraduates demonstrated awareness of the importance of disinfecting intraoral scanner tips by wiping with the surgical spirit.

To assess the attitudes of dental students, they were asked whether impression trays should be sterilized after each patient. Almost everyone responded affirmatively, emphasizing the importance of sterilizing impression trays after each patient.

CONCLUSIONS

This study reveals that the knowledge, practices, and attitudes of dental undergraduates and interns regarding the sterilization and disinfection of impression trays are inadequate when compared to postgraduates. This inadequacy increases the risk of disease transmission and cross-infection. Therefore, there is an urgent need to raise awareness among dental professionals about sterilization and disinfection protocols. Educating them on the importance of adhering to these protocols is crucial to minimize the risk of disease spread and ensuring patient and practitioner safety.

This study provides valuable insights into the knowledge and practices about the sterilisation and disinfection of impression trays among undergraduates, interns and postgraduates in their daily dental practices. However, its scope was confined to the state of Maharashtra, and the sample size was limited. Consequently, more extensive studies involving diverse regions and larger sample size seems necessary to gain a comprehensive understanding regarding the practise of sterilisation and disinfection protocols.

REFERENCES

1. Yuzbasioglu, E., Kurt, H., Turunc, R., & Bilir, H. (2014). Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC oral health, 14, 1-7.
2. Jain, A. R., & Fauzi, N. Q. B. A. (2018). Knowledge, attitude, and practice on various disinfectants used for impression materials among dental students and dental practitioners. Drug Invention Today, 10(1), 23-28.
3. Notle, W. (1982). Streptococci: in: Oral microbiology with basic microbiology and immunology.(edition4thed). St. Louis (MO): CV Mobsy Company, 28-326.

4. Owen, C. P., & Goolam, R. (1993). Disinfection of impression materials to prevent viral cross contamination: a review and a protocol. International Journal of Prosthodontics, 6(5).
5. Kohn, W. G., Collins, A. S., Cleveland, J. L., Harte, J. A., Eklund, K. J., & Malvitz, D. M. (2003). Guidelines for infection control in dental health-care settings-2003. MMWR Recomm Rep, 52(17), 1-61.
6. Council on Dental Materials, Instruments, and Equipment. (1988). Infection control recommendations for the dental office and the dental laboratory. The Journal of the American Dental Association, 116(2), 241-248.
7. Cottone, J. A., Young, J. M., & Dinyarian, P. (1990). Disinfection/sterilization protocols recommended by manufacturers of impression materials. International Journal of Prosthodontics, 3(4).
8. Bergman, B. O. (1989). Disinfection of prosthodontic impression materials: a literature review. International Journal of Prosthodontics, 2(6).
9. Poulos, J. G., & Antonoff, L. R. (1997). Disinfection of impressions. Methods and effects on accuracy. The New York State Dental Journal, 63(6), 34-36.
10. McCabe, J. F. (1990). Aplied dental materials. 7th Edicion. Buttler & Tanner Ltd, London, 1-27.
11. Van Noort, R., & Barbour, M. (2005). Introduction to dental materials (pp. 81-84). Mosby, UK.
12. Cottone, J. A., Terezhalmy, G. T., & Molinari, J. A. (1996). Practical infection control in dentistry. (No Title).
13. Gladwin, M. A., & Bagby, M. D. (2000). Clinical aspects of dental materials. (No Title).
14. Craig, R. G. (Ed.). (1980). Restorative dental materials. Mosby.
15. Del'Acqua, M. A., De Avila, É. D., Amaral, Â. L., Pinelli, L. A., & de Assis Mollo Jr, F. (2012). Comparison of the accuracy of plastic and metal stock trays for implant impressions. The International journal of oral & maxillofacial implants, 27(3), 544-550.
16. Cho, G. C., & Chee, W. W. (2004). Distortion of disposable plastic stock trays when used with putty vinyl polysiloxane impression materials. The Journal of prosthetic dentistry, 92(4), 354-358.
17. Fanoy, E. B., Cremer, J., Ferreira, J. A., Dittrich, S., van Lier, A., Hahné, S. J., ... & van Binnendijk, R. S. (2011). Transmission of mumps virus from mumps-vaccinated individuals to close contacts. Vaccine, 29(51), 9551-9556.
18. Iqbal, S., Kazmi, F., Asad, S., Mumtaz, M., & Khan, A. A. (2011). Dental caries and diabetes mellitus. Pakistan oral and dental journal, 31(1).
19. Asad, S., AWAISI, Z. H., & Bokhari, F. (2012). A survey on cross infection hazards associated with dental impression recording. Pakistan Oral & Dental Journal, 32(2).
20. Amin, F., Sheikh, A. A., Qureshi, A., & Abbas, M. (2014). Prevailing knowledge and practices about dental impressions disinfection. J Pak Dent Assoc, 23(4), 164-169.
21. Anwar, S., Ahmad, I., & Khalil, T. F. (2024). Knowledge, attitude and practice of infection control measures among dentists of Peshawar Pakistan: A Cross sectional study. Journal of Rehman College of Dentistry, 5(1).
22. Ukuoghene, I. N., Ololade, A. A., Olufunmilayo, A. M., & Lilian, E. (2017). Disinfecting dental impression materials-meeting the challenges in two tertiary hospitals in lagos Nigeria. Biomedical Journal of Scientific and Technical Research, 1-6.
23. Skaug, N. (1983). Proper monitoring of sterilization procedures used in oral surgery. International Journal of Oral Surgery, 12(3), 153-158.
24. Ostrander, F. D. (1970). Accepted Dental Therapeutics 1969–1970 a Historical Review. The Journal of the American Dental Association, 80(3), 589-592.
25. Fukuzaki, S. A. T. O. S. H. I. (2006). Mechanisms of actions of sodium hypochlorite in cleaning and disinfection processes. Biocontrol science, 11(4), 147-157.
26. Ishida, H., Nahara, Y., Tamamoto, M., & Hamada, T. (1991). The fungicidal effect of ultraviolet light on impression materials. The Journal of Prosthetic Dentistry, 65(4), 532-535.
27. Kim, S. Y., Kim, M. J., Han, J. S., Yeo, I. S., Lim, Y. J., & Kwon, H. B. (2013). Accuracy of dies captured by an intraoral digital impression system using parallel confocal imaging. International Journal of Prosthodontics, 26(2).
28. Kj, A. (2003). Phillips' science of dental materials. St. Louis: WB Saunders, 596, 41-43.

Original Research Paper

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Dental Science

"COMPARATIVE EVALUATION OF MACROESTHETIC OUTCOMES ACHIEVED BY REMOVABLE VERSUS FIXED TWIN BLOCK APPLIANCE: A CEPHALOMETRIC ANALYSIS"

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ABSTRACT

Aim: This study aimed to evaluate and compare the macroesthetic outcomes of removable versus fixed Twin Block appliances in growing patients with skeletal Class II malocclusion. **Methods:** A randomized controlled trial was conducted on 40 patients aged 8–15 years with Angle's Class II division 1 malocclusion and positive visual treatment objectives. Subjects were equally divided into two groups: Group A (removable Twin Block) and Group B (fixed Twin Block). Pre- and post-treatment lateral cephalograms were obtained, manually traced, and analyzed for soft tissue parameters, including the nasolabial angle and lip position relative to the E-line. Data were subjected to statistical analysis with a significance level of $p<0.05$. **Results:** Both groups demonstrated favorable soft tissue profile changes following functional appliance therapy. The nasolabial angle showed greater improvement in the removable group (mean change 5.85°), though this did not reach statistical significance ($p=0.06$). The upper lip position relative to the E-line demonstrated a statistically significant difference between groups, with the removable Twin Block producing greater retrusion ($p=0.02$). No significant intergroup difference was observed in the lower lip position ($p=0.83$). **Conclusions:** Removable and fixed Twin Block appliances are both effective in improving facial esthetics in growing Class II patients. However, removable Twin Blocks demonstrated marginally superior outcomes in enhancing upper lip position and nasolabial angle, suggesting greater potential for soft tissue profile refinement. Appliance selection should be guided by individual treatment objectives, growth potential, and compliance considerations.

KEYWORDS : Macroesthetics, Twin Block, removable appliance, fixed appliance, skeletal Class II malocclusion, facial esthetics.

Facial esthetics play a pivotal role in an individual's self-perception and psychological well-being. Among various components contributing to facial attractiveness, macroesthetic harmony-encompassing the proportional relationships between skeletal, dental, and soft tissue structures-holds significant importance.

A harmonious facial profile is often associated with beauty, thereby influencing how others view individuals and how they perceive themselves [1, 2]. Historically, Angle's philosophy emphasized achieving facial harmony based on classical ideals, believing that a "full complement of teeth" was essential for perfect balance and esthetics. This non-extraction approach dominated early orthodontics. However, this approach faced criticism from several experts, including Dr. Calvin Case and Tweed, who questioned its validity. They observed that non-extraction protocols led to poor stability and suboptimal esthetic outcomes. They advocated extractions to achieve better dental alignment and facial harmony [2, 3].

Numerous studies confirm that disharmonious facial features can negatively influence social perception, trigger bullying, and even limit career opportunities [4, 5]. For many individuals, the primary motivation is the enhancement of facial appearance. Consequently, one of the objectives of orthodontics is to establish a balanced, pleasing facial profile, rather than strictly conforming to normative skeletal and dental ideals [6, 7].

A comprehensive evaluation of dentofacial esthetics requires both static and dynamic assessments of the face. Clinically, this includes analyzing facial symmetry, the relationship between teeth and lips, and the influence of skeletal and dental structures on soft tissue drape [3]. Ackerman et al. introduced a hierarchical approach to esthetic diagnosis, classifying facial and dental esthetics into three primary domains:

- **Macroesthetics:** Concerned with facial proportions in all three dimensions
- **Miniesthetics**: Focuses on the relationship between the dentition and soft tissues, especially during smiling and speech.
- **Microesthetics**: Involves the finer details of individual teeth [8, 9].

The subjective nature of beauty complicates its measurement. Studies have shown that both dental professionals and laypersons vary in their perceptions of facial attractiveness [10]. Nonetheless, patient satisfaction with their facial and dental appearance remains a critical predictor of their expectations and perceived success of orthodontic treatment [11].

Functional appliances are commonly employed in growing patients with skeletal Class II malocclusion, particularly those with mandibular retrusion. Twin Block appliances are designed to advance the mandible and modulate craniofacial growth, resulting in both skeletal and soft tissue adaptations. Available in removable and fixed configurations, they are recognized for their clinical effectiveness, patient compliance, and distinct therapeutic advantages.[12, 13].

While earlier studies questioned the extent to which functional appliances enhanced facial attractiveness [14], more recent research indicates that both removable and fixed functional appliances can significantly improve the facial profile [15]. However, no conclusive evidence exists directly comparing the esthetic outcomes between removable and fixed Twin Block appliances, highlighting a gap in the literature.

In light of the growing importance of esthetics in treatment planning and patient satisfaction, this study aims to compare the macroesthetic outcomes in patients with skeletal Class II malocclusion treated with removable versus fixed Twin Block appliances. Using cephalometric analysis, this research intends to evaluate the relative improvement in facial harmony and profile balance offered by these two modalities.

AIM:
The purpose of this study is to evaluate the macroesthetics after removable versus fixed twin block appliance treatment

OBJECTIVE:
To evaluate macroesthetics after removable versus fixed twin block appliance therapy

MATERIALS AND METHODOLOGY:
Patients with skeletal class II malocclusion aged between 8-15 years reporting to the Department of Orthodontics were selected for this study. A total of 40 subjects who fulfilled the inclusion criteria were taken under the study and divided equally and randomly into 2 groups. Group A was treated with a removable twin block appliance, and Group B was treated with a fixed twin block appliance. The study involved a simple randomized sampling technique. Pre- and post-phase-1 lateral cephalograms were taken and traced manually. The observations after the completion of the study were subjected to statistical analysis, and objective conclusions from the acquired results were drawn. The study was conducted abiding by all human ethical principles as per the Declaration of Helsinki and guidelines of the Occupational Safety and Health Administration [OSHA].

Sample size and source:

Formula used:

$$n=\frac{(\sigma_1^2+\sigma_2^2/\kappa)(z_{1-\alpha/2}+z_{1-\beta/2)})^2}{\Delta^2}$$

The notation for the formula is:
n= sample size of per group
σ_1 = standard deviation of Group 1
$\sigma_{2=}$ standard deviation of Group 2
= difference in group means
= ratio = 1
$z_{1-\alpha/2}$= two-sided Z value (eg. Z=1.96 for 95% confidence interval).
$z_{1-\beta/2}$= power

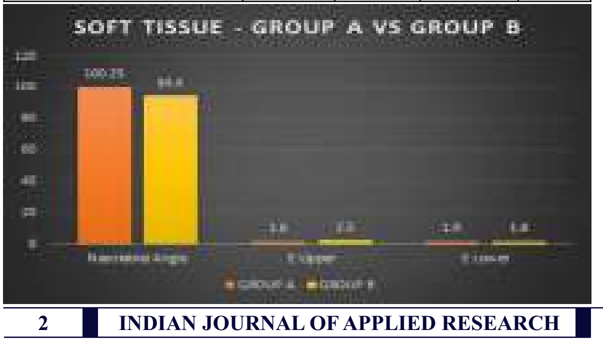
Methods Of Selection Of Study Subjects:
Inclusion Criteria-
1) Individuals with Angle's class II division 1 malocclusion
2) Individuals with an overjet greater than 5 mm
3) Individuals with positive VTO (Visual Treatment Objective)
4) Individuals in CVMI stage 3-5

Exclusion Criteria-
1) Individuals with Angle's class I malocclusion
2) Individuals with an overjet of less than 5 mm
3) Individuals with negative VTO (Visual Treatment Objective)
4) Individuals with craniofacial anomalies

RESULT
Group A Vs Group B

Soft Tissue Changes
The nasolabial angle and the lower lip position relative to the E line did not show a statistically significant difference. The upper lip position relative to the E-line demonstrated a significant difference

Measurement	POST group A	POST group B	Difference	P value
Nasolabial angle	100.25	94.4	5.85	0.06
E upper	1.6	2.5	-0.9	0.02
E lower	1.9	1.8	0.1	0.83



DISCUSSION
Facial esthetics has emerged as a cornerstone of orthodontic diagnosis and treatment planning, particularly in growing patients. With increasing emphasis on patient-centered care, the esthetic outcomes are now critically evaluated as functional and occlusal corrections. Among malocclusion patterns, skeletal Class II discrepancies — most often characterized by mandibular retrognathism — are not only prevalent but also prominently affect a patient's facial harmony and social self-perception. The Twin Block appliance has become one of the most popular functional appliances. Both removable and fixed variants of the Twin Block are used today, with varying indications based on patient cooperation and growth stage.

Despite the widespread use of both types of Twin Block appliances, there exists limited evidence comparing their outcomes in a controlled setting. Therefore, there was a need to conduct a well-structured study that could provide clear and comprehensive data on the effectiveness of Removable versus Fixed Twin Block appliances.

Previous studies have reported significant esthetic enhancements with these appliances:
- Toth and McNamara (1999) compared Twin Block and Frankel appliances and reported significant improvements in soft tissue convexity, upper lip retrusion, and increased chin prominence with the Twin Block, indicating improved facial profile.
- Baysal and Uysal (2013) examined the soft tissue effects of the Twin Block and Herbst appliance and found that both led to a significant increase in nasolabial angle and reduction in upper lip protrusion, with a slightly more pronounced effect in the removable Twin Block group.
- Illing et al. (1998) reported that both removable and fixed functional appliances improve soft tissue facial profile, but individual variability and appliance design elements, such as expansion screws and lip pads, can influence the degree of esthetic change.

In the present study, both the removable (Group A) and fixed (Group B) Twin Block appliances yielded notable improvements in the soft tissue profile
1. Nasolabial Angle**:**
o The intergroup difference was not statistically significant (p = 0.06), the greater improvement in the removable group aligns with the previous findings, which reported more pronounced soft tissue changes with the removable design.

2. Upper Lip Position (to E-line)**:**
o These results are consistent with the Toth and McNamara study**,** which emphasized the favorable upper lip positioning obtained using Twin Blocks compared to other appliances.

3. Lower Lip Position (to E-line)**:**
o This finding aligns with the results of Illing et al.**,** who noted that lower lip response is generally less variable across different functional appliances, likely due to its closer anatomical connection with the chin and mandible.

This subtle, but clinically relevant distinction emphasizes the importance of appliance selection based on individual treatment objectives. When facial esthetics and soft tissue profile refinement are key treatment priorities, the removable Twin Block may offer marginally better outcomes due to its skeletally driven mode of action, as opposed to the more dentally compensatory nature of fixed variants. These findings suggest removable Twin Block appliances may offer superior control over upper lip position and nasolabial angle-possibly due to better adjustability and incorporation of components like labial bows and selective acrylic trimming.

SUMMARY AND CONCLUSION
The comparative effects of fixed versus removable Twin Block appliances on soft tissue parameters remain a subject of ongoing investigation. Several previous studies have shown varying outcomes. Therefore, a study was conducted to compare the soft tissue effects of removable versus fixed Twin Block appliances in growing patients with skeletal Class II malocclusion

The study findings revealed that,
a) Removable twin block showed greater improvement in soft tissue profile, particularly upper lip retrusion and nasolabial angle increase,

indicating better hard-tissue-to-soft-tissue harmony may be due to less dental compensation.

Ultimately, appliance selection should be individualized, considering Growth potential, patient compliance, treatment objectives, and the desired balance between skeletal and dental effects.

LIMITATIONS AND FUTURE SCOPE

- The sample size, while statistically adequate, limits the generalizability of the findings.
- Soft tissue volumetric alterations were not assessed.
- Long-term stability was not evaluated.

Future studies incorporating 3D facial scans and photogrammetry would enrich our understanding. Additionally, patient-reported outcome measures (PROMs) should be integrated to bridge the gap between clinical findings and patient satisfaction.

REFERENCES

1. Sarver, D. M. (2001). The importance of incisor positioning in the esthetic smile: the smile arc. *American journal of orthodontics and dentofacial orthopedics*, *120*(2), 98-111.
2. Graber, L. W., Vanarsdall, R. L., Vig, K. W., & Huang, G. J. (1994). Orthodontics: current principles and techniques. *(No Title)*
3. Ackerman, J. L., Proffit, W. R., & Sarver, D. M. (1999). The emerging soft tissue paradigm in orthodontic diagnosis and treatment planning. *Clinical orthodontics and research*, *2*(2), 49-52.
4. Shaw, W. C. (1981). The influence of children's dentofacial appearance on their social attractiveness as judged by peers and lay adults. *American journal of orthodontics*, *79*(4), 399-415.
5. Newton, J. T., Prabhu, N., & Robinson, P. G. (2003). The impact of dental appearance on the appraisal of personal characteristics. *International Journal of Prosthodontics*, *16*(4).
6. Feu, D., de Oliveira, B. H., de Oliveira Almeida, M. A., Kiyak, H. A., & Miguel, J. A. M. (2010). Oral health-related quality of life and orthodontic treatment seeking. *American Journal of Orthodontics and Dentofacial Orthopedics*, *138*(2), 152-159.
7. Arnett, G. W., & Bergman, R. T. (1993). Facial keys to orthodontic diagnosis and treatment planning. Part I. *American journal of orthodontics and dentofacial orthopedics*, *103*(4), 299-312.
8. Sarver, D. M., & Ackerman, M. B. (2003). Dynamic smile visualization and quantification: Part 2. Smile analysis and treatment strategies. *American journal of orthodontics and dentofacial orthopedics*, *124*(2), 116-127.
9. Zachrisson, B. U. (1998). Esthetic factors involved in anterior tooth display and the smile: vertical dimension.
10. Kokich Jr, V. O., Asuman Kiyak, H., & Shapiro, P. A. (1999). Comparing the perception of dentists and lay people to altered dental esthetics. *Journal of Esthetic and Restorative Dentistry*, *11*(6), 311-324.
11. Phillips, C., Tulloch, C., & Dann, C. (1992). Rating of facial attractiveness. *Community dentistry and oral epidemiology*, *20*(4), 214-220.
12. Clark, W., & Clark, W. J. (2014). *Twin block functional therapy*. JP Medical Ltd.
13. Toth, L. R., & McNamara Jr, J. A. (1999). Treatment effects produced by the Twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated Class II sample. *American Journal of Orthodontics and Dentofacial Orthopedics*, *116*(6), 597-609.
14. Tulloch, J. C., Phillips, C., & Proffit, W. R. (1998). Benefit of early Class II treatment: progress report of a two-phase randomized clinical trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, *113*(1), 62-74.
15. Baysal, A., & Uysal, T. (2013). Soft tissue effects of Twin Block and Herbst appliances in patients with Class II division 1 mandibular retrognathy. *The European Journal of Orthodontics*, *35*(1), 71-81.

ORIGINAL RESEARCH PAPER

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"VERTICAL EFFECTS OF FUNCTIONAL APPLIANCE THERAPY IN GROWING PATIENTS WITH SKELETAL CLASS II MALOCCLUSION –A SYSTEMATIC REVIEW AND META-ANALYSIS"

Dentistry

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ABSTRACT

Aim: To evaluate the effectiveness of functional appliance therapy in the vertical dimension in growing patients with skeletal class II malocclusion **Methods:** The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and was registered in PROSPERO with the registration number CRD42023480848. A thorough search of databases was conducted till December 2023 to identify studies evaluating the effectiveness of functional appliance therapy in the vertical dimension in growing patients with skeletal class II malocclusion. Quality assessment was performed using the Cochrane risk of bias (ROB) -2 tool for randomized controlled trials (RCTs), evaluating each study's domains through Review Manager (RevMan) software version 5.4.1. The standardized mean difference (SMD) served as the summary statistic measure, employing a random-effect model with a significance threshold set at $p<0.05$. **Results:** Five studies met the eligibility criteria and underwent qualitative synthesis, with five studies in meta-analysis. Upon quality assessment, the studies demonstrated a low risk of bias, ensuring a comprehensive evaluation of the evidence base. Outcomes like lower anterior facial height and total anterior facial height were assessed quantitatively. Pooled estimate through SMD favored the functional appliance group over the control or other modality group ($p>0.05$). The funnel plot did not reveal the presence of any heterogeneity indicating the absence of publication bias. **Conclusion:** The treatment effects of FAs on the skeletal tissues in patients with Class II malocclusion were probably of clinical importance. The treatment of Class II malocclusion with FAs was associated with stimulation of mandibular growth and significant dentoalveolar and soft tissue changes. Along with the sagittal changes, functional appliances also bring about vertical changes. Under the limitations of the number of available studies and total samples for this systematic review, the following conclusions could be made: 1. Functional appliances bring about a significant increase in lower anterior facial height (ANS- Me) of individuals with skeletal class II malocclusion 2. Total anterior facial height (N-Me) shows a significant increase in growing individuals with skeletal class II malocclusion

KEYWORDS

Growing patients, skeletal class II malocclusion, mandibular retrognathism, removable functional appliance, fixed functional appliance, lower anterior facial height, total anterior facial height, systematic review

INTRODUCTION:

Several orthodontic patients are seen with class II dentofacial deformities. Among children within the age range of 6 to 15 years, the occurrence of skeletal class II malocclusions is at 37%. **Mc Namara** reported mandibular retrusion as the most common characteristic of Class II malocclusion.[1] In growing patients, two-phase treatment of Class II skeletal malocclusions, which includes growth modification with functional appliances followed by orthodontic treatment with fixed appliances, has been advocated as an appropriate treatment approach.[2,3] The primary objectives of growth modification in all orthodontic treatment approaches are to correct skeletal discrepancy and enhance facial aesthetics.[4] Successful correction of Class II Division 1 malocclusion can be achieved by generating a combination of dental and skeletal effects using both removable and fixed functional appliances.[5] Functional appliances produce varying effects depending on their design, which has led to a variety of studies comparing different types of functional appliances.[6] The favorable treatment outcomes of functional appliances based on mandibular growth, attributed either as a mandibular length augmentation or effective condyle growth.[7,8,9,10] Furthermore, some researchers have supported a restriction effect on the maxilla.[11,12,13,14,15] Several studies utilizing functional appliances have observed skeletal changes in the anteroposterior dimension and increase in vertical facial height in the short term.[16,17,18]

The Twin-block (TB) appliance can lead to undesirable treatment effects, including mandibular incisor proclination, an increase in vertical facial dimension (which is harmful in high-angle patients), clockwise rotation of the maxillary plane, and a limited increase in mandibular growth that may not be maintained in the long term..[19,20,21,22] **McDonagh et al** reported an increase in the anterior facial height and that the soft tissue changes tended to reflect the changes seen in the hard tissues. A significant portion of the clinical data on the effects of functional appliance therapy has been derived from the analysis of pre- and post-treatment results of selectively successful cases. Previous researchers have often failed to include an untreated control group in their study design, while others have used patients of varying ages, unsuccessful cases, or those undergoing alternative forms of orthodontic treatment.[23]

While the sagittal effects of functional appliances have been studied in the dental literature, the vertical effects have not been compared. Therefore, this systematic review and meta-analysis aim to assess the changes in the vertical dimension resulting from using various functional appliances.

Aim:

The current systematic review aims to evaluate the effectiveness of functional appliance therapy in the vertical dimension in growing patients with skeletal class II malocclusion

Methodology:

Protocol And Registration

This systematic review was conducted and performed according to the preferred reporting items for systematic review and meta-analysis (PRISMA) statement[29] After searching for previously registered similar studies, the Review protocol of this Systematic review was registered on November 20,2023 with the National Institute of Health Research database and registered in Prospective Registration of Systematic Review (PROSPERO)- CRD42023480848.

Information Sources And Search

A comprehensive electronic search was conducted up until December 2023, covering studies published over the past 33 years (1990 to 2023) using the following databases: PubMed, Google Scholar, and EBSCOhost to retrieve English-language articles. Searches in clinical trial databases, cross-referencing, and grey literature were carried out using Google Scholar, Greylist, and Open Grey.

A manual search was also performed in various journals, including orthodontic journals such as the American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontist, European Journal of Orthodontics, Journal of Orthodontics, Orthodontics, Journal of Oral Biology and Craniofacial Research, and Journal of Craniofacial Research.

Relevant keywords and Medical Subject Heading (MeSH) terms were selected and combined using Boolean operators like AND. The data was searched using the following keywords and their combinations: "skeletal malocclusion" (MeSH) AND "fixed appliance" (MeSH); "orthodontics" (MeSH) AND "vertical dimension" (MeSH); "overbite" (MeSH) AND "overjet" (MeSH) AND "malocclusions" (MeSH); "class II molar & canine relationship" (MeSH) AND "maxilla and mandible" (MeSH) AND "comparative study" AND "longitudinal study" AND "prospective study" (MeSH); "randomized controlled trials" (MeSH).

In addition to the electronic search, a hand search was performed, and the reference lists of selected articles were reviewed. The reference lists of identified studies and relevant reviews were also examined for any additional studies.

Study Selection And Eligibility Criteria:

The review question aimed to assess the effectiveness of functional appliance therapy in the vertical dimension for growing patients with skeletal Class II malocclusion. Inclusion and exclusion criteria were established prior (Table 1). After removing duplicates, articles were screened based on title, abstract, and full text. If the decision based on the title and abstract was inconclusive, the full-text article was obtained. In cases where an identical study was published in multiple languages, the English version was considered.

Table 1. Eligibility Criteria Used For The Study Selection.

Category	Inclusion Criteria	Exclusion Criteria
Participant Characteristics	Studies on human patients with skeletal class II malocclusion with the retruded mandible of age between 10 to 15 yrs of any gender.	1) Patients with craniofacial syndromes and/or cleft lip palate 2) Patients with temporomandibular joint disorders
Intervention	The intervention involves using Removable functional appliance or Fixed functional appliance for treating skeletal class II malocclusion with mandibular retrusion.	Patient with skeletal class II malocclusion treated with methods other than removable or fixed functional appliances.
Comparator/Control	Untreated patients with Skeletal class II malocclusion with mandibular retrusion.	
Outcome	1) Evaluation of lower anterior facial height with removable or fixed functional appliances. 2) Evaluation of total anterior facial height with removable or fixed functional appliances.	Any other outcome reported
Study Design	1) Randomized controlled trials 2) Prospective controlled clinical trials 3) Studies carried out in the time period of 1990 to December 2023 4) Studies carried out in any country 5)Full articles in English	1) Animal Studies 2) Unsupported opinion of experts 3) Replies to the author/editor 4) Interviews 5) Commentaries 6)Books/conferences/abstracts 7) Summaries 8) Cross-sectional surveys 9) Case series 10) Case reports or reports of cases 11) Case–control observational studies 12) Cohort studies 13) Retrospective clinical trials 14) Narrative reviews 15) Systematic reviews 16) Meta-analyses 17) Non -English articles

Screening Process

The search and screening process, following the predefined protocol, was carried out by two reviewers. The selection of articles occurred in two phases. In phase one, both reviewers examined the titles and abstracts of all articles, excluding those that did not meet the inclusion criteria. In phase two, the full articles were independently reviewed and assessed by the same reviewers. Any disagreements were resolved through discussion, and if a consensus could not be reached, a third reviewer was involved to make the final decision. The final selection of articles was made through mutual agreement among all three authors.

Quality Assessment Of Included Studies

The methodological quality of the included studies was assessed using the Cochrane Collaboration Risk of Bias (ROB)-2 tool. This tool covers various domains such as random sequence generation (selection bias), allocation concealment (selection bias), blinding of personnel and equipment (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other potential biases, evaluated through signaling questions in Review Manager (RevMan) 5.4.1 software. The overall risk for each study was categorized as low, moderate, or high based on these domains and criteria. A study was considered to have a low overall risk only if all domains were rated as low risk. A high overall risk was assigned if one or more domains were rated as high risk. Studies were assigned a moderate risk assessment if one or more domains were rated as uncertain, with none at high risk.

Statistical Analysis

The standardized mean difference (SDM) with 95% CI was calculated for continuous outcomes. A fixed effects model (Mantel-Haenszel method) was used if there was no heterogeneity ($p > 0.05$ or I-squared $\le 24\%$), otherwise a random effects model (Der Simonian- Laird method) was used.[33] All statistical analyses were performed using RevMan 5.4.1 (Cochrane Collaboration, Software Update, Oxford, UK). The significance level was kept at $p<0.05$.

Assessment Of Heterogeneity

The significance of any discrepancies in the treatment effect estimates across different trials was assessed using Cochran's test for heterogeneity and the I^2 statistic, which indicates the percentage of total variation across studies attributed to heterogeneity rather than chance. Heterogeneity was considered statistically significant if $p < 0.1$. According to the Cochrane Handbook, I^2 values can be interpreted as follows: (1) 0 to 40% suggests low heterogeneity, (2) 30% to 60% indicates moderate heterogeneity, (3) 50% to 90% suggests substantial heterogeneity, and (4) 75% to 100% represents considerable heterogeneity.[30]

Investigation Of Publication Bias

To test for the presence of publication bias, the relative symmetry of the individual study estimates was assessed around the overall estimates using Begg's funnel plot. A funnel plot (plot of the effect size versus standard error) was drawn. Asymmetry of the funnel plot may indicate publication bias and other biases related to sample size, although asymmetry may also represent a true relationship between trial size and effect size.[31]

Data Collection Process And Data Items

After removing duplicates, the reference lists of the included studies were screened, resulting in the exclusion of 116 studies. The full-text articles were then assessed for eligibility, and those that did not meet the inclusion criteria were excluded. Six studies met the eligibility criteria and were included in the qualitative synthesis. These six studies were also included in the meta-analysis. The flowchart illustrating the identification, inclusion, and exclusion of studies is

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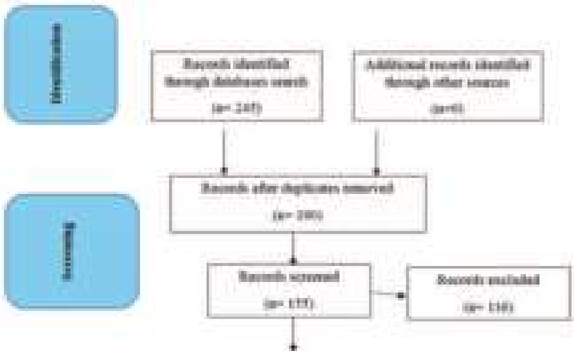
shown in Figure 1 below.



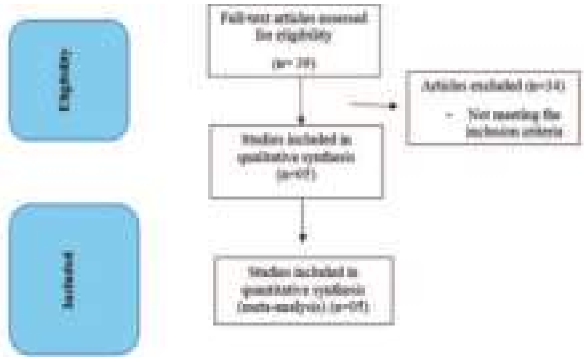


Figure.1 - PRISMA flow diagram for the selection of studies

Table 2 – Demographic data of the five studies included in the current systematic review

Study	Design	Setting	Characteristics of patient	Intervention	No of patients	Age in Years (Mean)	Materials/ Measures	Assessment of results	Conflict of Interest
Colin Nelson (1993)[24]	Randomized controlled trial	Dunedin, New Zealand	Angles Class II division 1 malocclusion with mandibular retrognathia.	Gp 1 -Frankel function regulator Gp 2- Harvold activator Gp 3- Untreated control group	Gp 1: 13 Gp 2: 12 Gp 3: 17	Gp 1: 11.70 Gp 2: 11.70 Gp 3: 11.53	Investigation was carried out on lateral cephalograms obtained just before insertion of Frankel function regulator appliance and activator appliance	Skeletal changes: Total anterior facial height, lower anterior facial height increment in the Frankel function regulator group and Harvold activator group	Not stated
David O Morris (1998)[25]	Prospective clinical study	The Royal London Hospital, UK	Skeletal Angle Class II division 1 malocclusion with a deficient mandible	Gp 1 -Bass appliance Gp 2 -Bionatar appliance Gp 3- Twin block appliance Gp4- Untreated control group	Gp 1: 13 Gp 2: 18 Gp 3: 16 Gp 4: 20	Gp 1: 12.5 Gp 2: 11.8 Gp 3: 11.5 Gp 4: 11.2	Lateral cephalometry and 3D Analysis were done before and immediately after treatment.	Skeletal Changes: Total anterior facial height, lower anterior facial height increment in bass, bionatar and twin block appliance group	Not stated
Heather M. Illing et al (1998)[26]	Randomized controlled Trial	The Royal London Hospital, UK	Skeletal class II malocclusion with Mandibular retrognathia	Gp 1 -Bass appliance Gp 2 -Bionatar appliance Gp 3- Twin block appliance Gp4- Untreated control group	Gp 1: 13 Gp 2: 18 Gp 3: 16 Gp 4: 20	Gp 1: 12.5 Gp 2: 11.8 Gp 3: 11.5 Gp 4: 11.2	Lateral cephalometric radiographs were taken immediately before (T1) and after removal of the bass, bionatar and twin block appliance (T2) to compare treatment outcome	Skeletal Measurements: Total anterior facial height, lower anterior facial height increment in bass, bionatar and twin block appliance group	Not stated
Asli Baysal et al (2014)[27]	Prospective clinical trial	Izmir Katip Celebi University, Turkey	Skeletal Angles Class II malocclusion with a deficient mandible	Gp 1: Herbst Gp 2: Twin Block Gp 3: Untreated control group	Gp 1: 20 Gp 2: 20 Gp 3: 20	Gp1: 12.74 GP 2: 13.0 Gp 3: 12.17	Lateral cephalometric radiographs were taken immediately before (T1) and after removal of the herbst and twin block appliance (T2) to compare treatment outcomes	Skeletal changes: Total anterior facial height, lower anterior facial height increment in herbst and twin block appliance group	Not stated
Seniz Karacay et al (2006)[28]	Prospective clinical trial	Gulhane Military Med ical Academy.	Skeletal Angles Class II malocclusion with a deficient mandible	Gp 1: Forsus Gp 2: Jasper Gp 3: Untreated control group	Gp 1: 16 Gp 2: 16 Gp 3: 16	Gp1: 13.6 GP 2: 14.0 Gp 3: 13.8	Lateral cephalometric radiographs were taken immediately before (T1) and after removal of the Forsus and jasper jumper appliance (T2) to compare treatment outcomes	Skeletal changes: Total anterior facial height, lower anterior facial height increment in Forsus and Jasper Jumper appliance group	Not stated

Assessment of methodological Quality of included studies

All the included studies were largely comparable in methodological quality. All the included studies has low risk of bias with all the respected domains. The highest risk of bias was seen for incomplete outcome data and selective reporting.

Domains of blinding of random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment have the lowest risk of bias by included studies. Risk of bias of included studies through Cochrane risk of bias (ROB)-2 tool is depicted in **Figure 2 and 3** as shown below

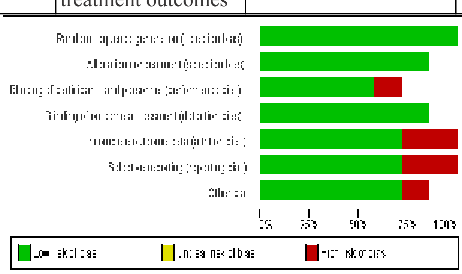


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Figure 2: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

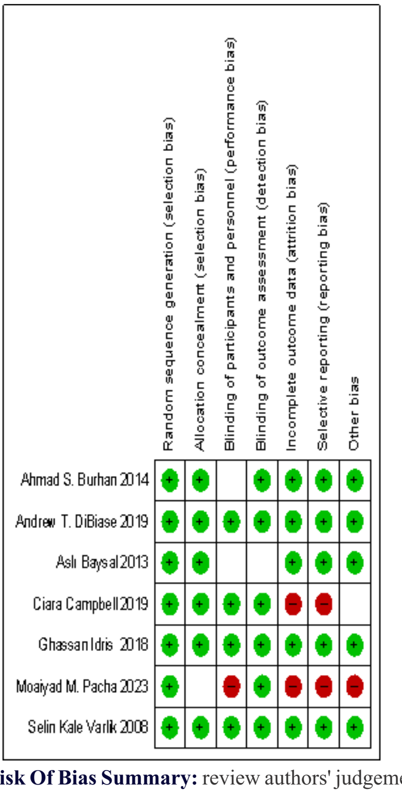

Figure 3: Risk Of Bias Summary: review authors' judgements about each risk of bias item for each included study

RESULT:

Study Selection

The search strategy resulted in 245 articles. A total of 116 records were excluded on the basis of screening of title and abstract. The full texts of 39 articles were obtained and assessed for eligibility. Respecting all selection phases based on the eligibility criteria, 5 articles qualified for final analysis. Figure 1 displays the different steps of the selection process entered in the PRISMA flow chart.

Study Characteristics

All the studies took place in a university setting. Growing patients with skeletal class II malocclusion with mandibular retrognathy were included with a mean age of 13.07 years. Patients were divided into two groups (Treated with removable functional appliance or fixed functional appliance and Untreated control group). Studies provided hard and soft tissue cephalometric outcomes based on lateral cephalometric analysis. All articles included in this review had a low risk of bias (Figure 2).

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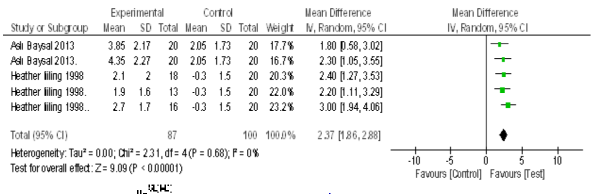

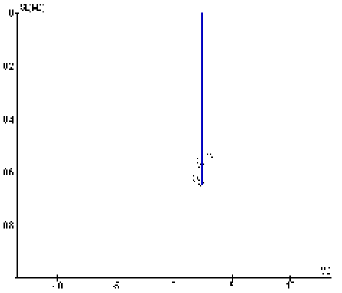

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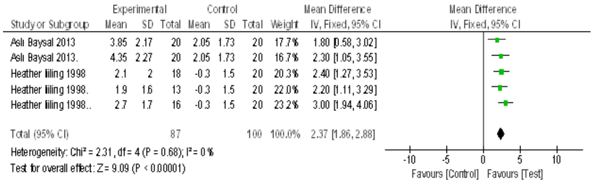

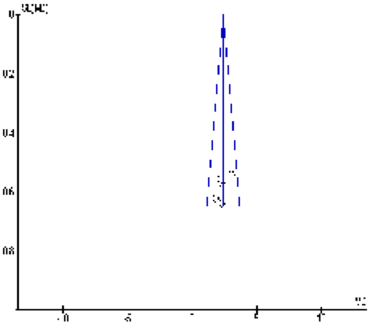

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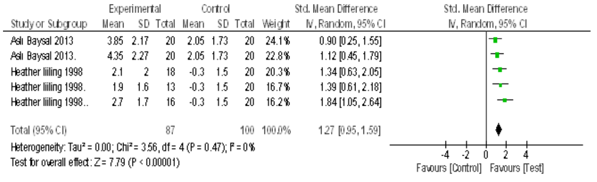

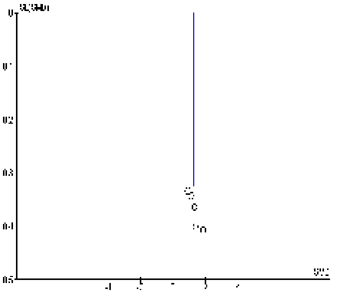

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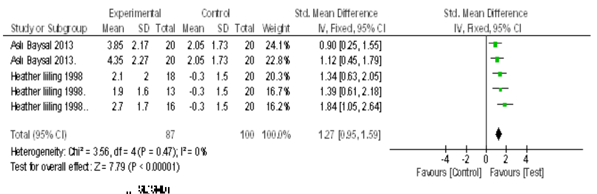

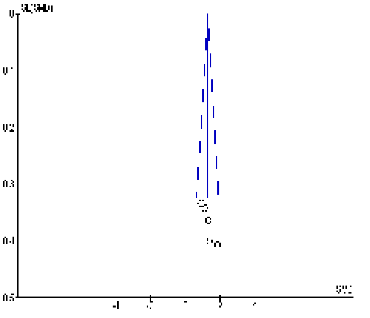

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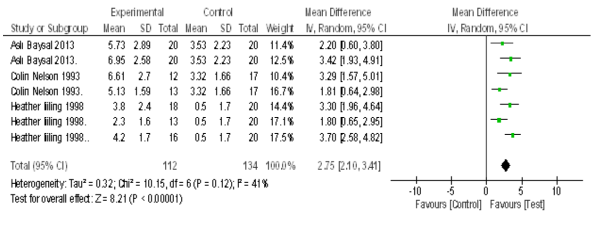

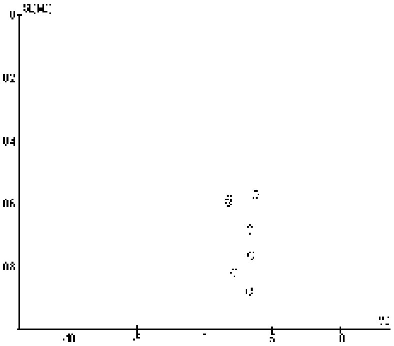

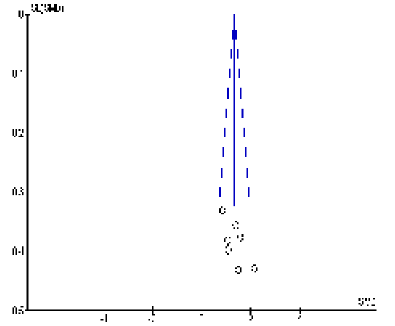

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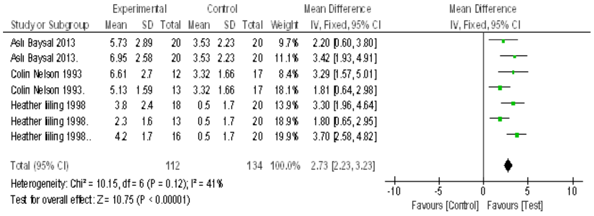
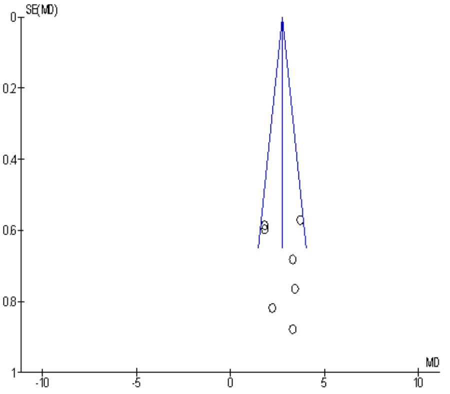


Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Aslı Baysal 2013	5.73	2.89	20	3.53	2.23	20	9.7%	2.20 [0.60, 3.80]
Aslı Baysal 2013.	6.95	2.58	20	3.53	2.23	20	11.1%	3.42 [1.93, 4.91]
Colin Nelson 1993	6.61	2.7	12	3.32	1.66	17	8.4%	3.29 [1.57, 5.01]
Colin Nelson 1993.	5.13	1.59	13	3.32	1.66	17	18.1%	1.81 [0.64, 2.98]
Heather liiling 1998	3.8	2.4	18	0.5	1.7	20	13.9%	3.30 [1.96, 4.64]
Heather liiling 1998.	2.3	1.6	13	0.5	1.7	20	18.9%	1.80 [0.65, 2.95]
Heather liiling 1998..	4.2	1.7	16	0.5	1.7	20	19.9%	3.70 [2.58, 4.82]
Total (95% CI)			112			134	100.0%	2.73 [2.23, 3.23]

Heterogeneity: Chi² = 10.15, df = 6 (P = 0.12); I² = 41%
Test for overall effect: Z = 10.75 (P < 0.00001)



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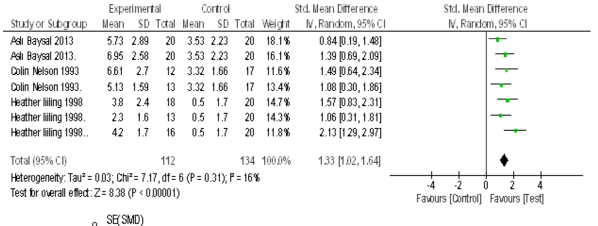
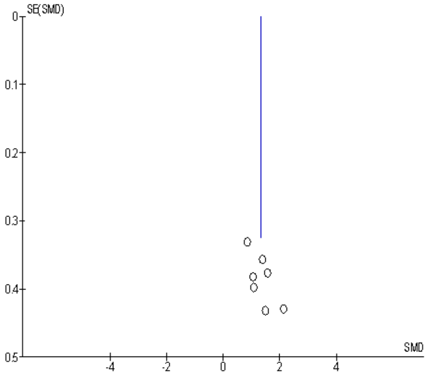


Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Aslı Baysal 2013	5.73	2.89	20	3.53	2.23	20	18.1%	0.84 [0.19, 1.48]
Aslı Baysal 2013.	6.95	2.58	20	3.53	2.23	20	16.1%	1.39 [0.69, 2.09]
Colin Nelson 1993	6.61	2.7	12	3.32	1.66	17	11.6%	1.49 [0.64, 2.34]
Colin Nelson 1993.	5.13	1.59	13	3.32	1.66	17	13.4%	1.08 [0.30, 1.86]
Heather liiling 1998	3.8	2.4	18	0.5	1.7	20	14.7%	1.57 [0.83, 2.31]
Heather liiling 1998.	2.3	1.6	13	0.5	1.7	20	14.3%	1.06 [0.31, 1.81]
Heather liiling 1998..	4.2	1.7	16	0.5	1.7	20	11.8%	2.13 [1.29, 2.97]
Total (95% CI)			112			134	100.0%	1.33 [1.02, 1.64]

Heterogeneity: Tau² = 0.03; Chi² = 7.17, df = 6 (P = 0.31); I² = 16%
Test for overall effect: Z = 8.38 (P < 0.00001)



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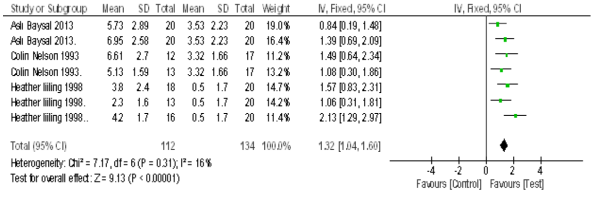

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Aslı Baysal 2013	5.73	2.89	20	3.53	2.23	20	19.0%	0.84 [0.19, 1.48]
Aslı Baysal 2013.	6.95	2.58	20	3.53	2.23	20	16.4%	1.39 [0.69, 2.09]
Colin Nelson 1993	6.61	2.7	12	3.32	1.66	17	11.2%	1.49 [0.64, 2.34]
Colin Nelson 1993.	5.13	1.59	13	3.32	1.66	17	13.2%	1.08 [0.30, 1.86]
Heather liiling 1998	3.8	2.4	18	0.5	1.7	20	14.7%	1.57 [0.83, 2.31]
Heather liiling 1998.	2.3	1.6	13	0.5	1.7	20	14.2%	1.06 [0.31, 1.81]
Heather liiling 1998..	4.2	1.7	16	0.5	1.7	20	11.4%	2.13 [1.29, 2.97]
Total (95% CI)			112			134	100.0%	1.32 [1.04, 1.60]

Heterogeneity: Chi² = 7.17, df = 6 (P = 0.31); I² = 16%
Test for overall effect: Z = 9.13 (P < 0.00001)

DISCUSSION:

Summary Of Evidence

This systematic review involved data from 187 Class II patients. These included 249 treated patients with functional appliances (FA) and 122 untreated patients. The studies were conducted from 2 randomized controlled trials (RCTs) and 3 prospective clinical trials (Pcct). The skeletal and dental changes assessed by radiographic methods in treating Class II malocclusion were reviewed for removable and fixed functional appliances.

In the **1993** study by **Colin Nelson et al**., it was found that total anterior facial height increased by 5.13 mm (SD = 1.59 mm) after using the Frankel appliance, and by 6.61 mm (SD = 2.70 mm) after applying the activator, compared to the control group, which showed an increase of only 3.32 mm (SD = 1.66 mm). Both appliance groups demonstrated a notable increase in anterior face height (N-Me). Similar changes were observed in other studies at the onset of functional appliance treatment, such as those by Chang et al. Furthermore, the increase in N-Me was significantly correlated with a rise in molar height in both appliance groups.

In a **2008** study by **Selin Kale Varlik**, the mean difference in lower anterior facial height changes was reported as 1.7 mm (SD = 1.8 mm) for the Bass appliance, 2.0 mm (SD = 2.6 mm) for the Bionator appliance, and 2.2 mm (SD = 2.0 mm) for the Twin Block appliance. In comparison, the control group had a mean difference of -0.5 mm (SD = 2.3 mm). The study also found the mean difference in total anterior facial height changes to be 1.9 mm (SD = 1.8 mm) for the Bass appliance, 4.0 mm (SD = 2.4 mm) for the Bionator appliance, and 4.5 mm (SD = 1.9 mm) for the Twin Block appliance. The control group showed a mean difference of 0.6 mm (SD = 2.4 mm

The control group showed a slight reduction in lower anterior facial height, with a mean decrease of 0.3 mm and a standard deviation of 1.5 mm. In contrast, the treatment groups demonstrated significantly greater increases, with the most notable clinical changes observed. The Twin Block group had the largest increase, with a mean difference of 2.7 mm and a standard deviation of 1.7 mm. This was followed by the Bionator group, which had a mean difference of 2.1 mm and a standard deviation of 2.0 mm, and the Bass group, showing a mean difference of 1.9 mm and a standard deviation of 1.6 mm. Clark (1995) reported a significant increase in total vertical face height with Twin Block therapy, with increases of 6.29 mm in males and 4.93 mm in females over 12 months. Cura et al. (1996) observed an increase in total face height with Bass therapy, reporting a mean difference of 3.4 mm and a standard deviation of 2.1 mm, while the Activator group showed a mean difference of 4.6 mm and a standard deviation of 1.8 mm, as noted in a **1998** study by **Heather Illing et al**.

Seniz Karacay et al., **2005** reported the mean difference in total anterior facial height between the Forsus appliance and the control group was 5.03 mm, with a standard deviation of 0.34 mm. For the Jasper Jumper, the mean difference compared to the control group was 4.47 mm, with a standard deviation of 0.34 mm. Additionally, the mean difference in lower anterior facial height between the Forsus appliance and the control group was 4.87 mm (SD = 0.29 mm), while for the Jasper Jumper, the mean difference was 5.00 mm (SD = 0.29 mm) compared to the control group.

An increase in both lower anterior and posterior face heights is consistently observed following Twin Block (TB) therapy. Toth and McNamara (1999) documented a 3.0 mm increase in anterior face height, while Lund and Sandler (1998) reported a 2.6 mm increase in total anterior face height compared to control groups. Mills and

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McCulloch (1998) also noted significant increases relative to controls, with a 3.8 mm increase in total anterior face height. When evaluating the increase in lower anterior face height during TB treatment, it is important to consider the impact of acrylic contouring. Additionally, Pancherz (1982) reported a 1.8 mm increase in lower anterior face height with a banded Herbst design.

In a **2013** study by **Asli Baysal et al.**, the mean difference in total anterior face height with the Herbst appliance was 6.95 mm, with a standard deviation of 2.58 mm. The Twin Block appliance showed a mean difference of 5.73 mm (SD = 2.89 mm), while the control group had a mean difference of 3.53 mm (SD = 2.23 mm). For lower anterior face height, the Herbst appliance resulted in a mean difference of 4.35 mm (SD = 2.27 mm), while the Twin Block appliance showed a mean difference of 3.85 mm (SD = 2.17 mm). In contrast, the control group exhibited a mean difference of 2.05 mm (SD = 1.73 mm).

An increase in the vertical dimension will likely be noticeable to a layperson. Therefore, it is important to assess changes in both the sagittal and vertical dimensions. This systematic review and meta-analysis also demonstrate a significant increase in both lower anterior facial height and total anterior facial height.

CONCLUSION

According to the existing evidence, the treatment effects of functional appliances were associated with stimulation of mandibular growth and with more pronounced dentoalveolar and soft tissue changes. Along with the sagittal changes functional appliances bring about vertical changes.

Under the limitations of the number of available studies and total samples for this systematic review, the following conclusions could be made:

1. Functional appliances bring about significant changes in lower anterior facial height (ANS- Me) of individuals with skeletal class II malocclusion
2. Total anterior facial height (N-Me) change was statistically significant in growing individuals with skeletal class II malocclusion
3. Patient and appliance-related factors might influence the outcome of functional appliance treatment

Limitations:

- Based on limited evidence functional appliances are effective in increasing total face height as well as lower anterior face height in children; however there remains insufficient evidence. Further well-designed randomized controlled trials are required to assess changes in vertical dimensions with functional appliances.

Future Scope:

- Three-dimensional quantification of the soft tissue changes is required to overcome current limitations in our understanding of the soft tissue changes obtained after the use of the Functional appliance in Class II division 1 malocclusion patients.

Abbrevations:

FAs: Functional appliances
RFAs: Removable functional appliances
FFAs: Fixed functional appliances
RCTs: Randomized controlled trials
PRISMA: Preferred reporting items for systematic review and meta-analysis
ROB: Risk of bias
MD: Mean deviation
SMD: Standard mean difference
TB: Twin block
Gp 1: Group 1
Gp 2: Group 2
Gp 3: Group 3
Gp 4: Group 4
T1: Before appliance delivery
T2: After appliance delivery

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Disclosure Of Interest:

The authors declare that they have no competing interests.
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Equal participation of all the authors.

REFERENCES:

1. McNAMARA Jr, J. A. (1981). Components of Class II malocclusion in children 8–10 years of age. The Angle Orthodontist, 51(3), 177-202.
2. Keeling, S. D., Wheeler, T. T., King, G. J., Garvan, C. W., Cohen, D. A., Cabassa, S., ... & Taylor, M. G. (1998). Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. American Journal of Orthodontics and Dentofacial Orthopedics, 113(1), 40-50.
3. Tulloch, J. C., Proffit, W. R., & Phillips, C. (2004). Outcomes in a 2-phase randomized clinical trial of early Class II treatment. American Journal of Orthodontics and Dentofacial Orthopedics, 125(6), 657-667.
4. Varlık, S. K., Gültan, A., & Tümer, N. (2008). Comparison of the effects of Twin Block and activator treatment on the soft tissue profile. The European Journal of Orthodontics, 30(2), 128-134.
5. Batista, K. B., Thiruvenkatachari, B., Harrison, J. E., & D O'Brien, K. (2018). Orthodontic treatment for prominent upper front teeth (Class II malocclusion) in children and adolescents. Cochrane Database of Systematic Reviews, (3).
6. Bishara, S. E., & Ziaja, R. R. (1989). Functional appliances: a review. American Journal of Orthodontics and Dentofacial Orthopedics, 95(3), 250-258.
7. Paulsen, H. U., Karle, A., Bakke, M., & Herskind, A. (1995). CT-scanning and radiographic analysis of temporomandibular joints and cephalometric analysis in a case of Herbst treatment in late puberty. The European Journal of Orthodontics, 17(3), 165-175.
8. McNamara Jr, J. A., Howe, R. P., & Dischinger, T. G. (1990). A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion. American journal of orthodontics and dentofacial orthopedics, 98(2), 134-144.
9. Franchi, L., Baccetti, T., & McNamara Jr, J. A. (1999). Treatment and posttreatment effects of acrylic splint Herbst appliance therapy. American journal of orthodontics and dentofacial orthopedics, 115(4), 429-438.
10. Woodside, D. G., Metaxas, A., & Altuna, G. (1987). The influence of functional appliance therapy on glenoid fossa remodeling. American Journal of Orthodontics and Dentofacial Orthopedics, 92(3), 181-198.
11. Covell Jr, D. A., Trammell, D. W., Boero, R. P., & West, R. (1999). A cephalometric study of class II Division 1 malocclusions treated with the Jasper Jumper appliance. The Angle Orthodontist, 69(4), 311-320.
12. Croft, R. S., Buschang, P. H., English, J. D., & Meyer, R. (1999). A cephalometric and tomographic evaluation of Herbst treatment in the mixed dentition. American journal of orthodontics and dentofacial orthopedics, 116(4), 435-443.
13. Hägglund, P., Segerdal, S., & Forsberg, C. M. (2008). The integrated Herbst appliance—treatment effects in a group of adolescent males with Class II malocclusions compared with growth changes in an untreated control group. The European Journal of Orthodontics, 30(2), 120-127.
14. Küçükkeleş, N., İlhan, I., & Orgun, İ. A. (2007). Treatment efficiency in skeletal Class II patients treated with the Jasper jumper: a cephalometric evaluation. The Angle Orthodontist, 77(3), 449-456.
15. Lai, M., & McNamara Jr, J. A. (1998, March). An evaluation of two-phase treatment with the Herbst appliance and preadjusted edgewise therapy. In Seminars in orthodontics (Vol. 4, No. 1, pp. 46-58). WB Saunders.
16. Gill, D. S., & Lee, R. T. (2005). Prospective clinical trial comparing the effects of conventional Twin-block and mini-block appliances: Part 1. Hard tissue changes. American journal of orthodontics and dentofacial orthopedics, 127(4), 465-472.
17. Lee, R. T., Kyi, C. S., & Mack, G. J. (2007). A controlled clinical trial of the effects of the Twin Block and Dynamax appliances on the hard and soft tissues. The European Journal of Orthodontics, 29(3), 272-282.
18. Ehsani, S., Nebbe, B., Normando, D., Lagravere, M. O., & Flores-Mir, C. (2015). Short-term treatment effects produced by the Twin-block appliance: a systematic review and meta-analysis. European Journal of Orthodontics, 37(2), 170-176.
19. Lund, D. I., & Sandler, P. J. (1998). The effects of Twin Blocks: a prospective controlled study. American journal of orthodontics and dentofacial orthopedics, 113(1), 104-110.
20. Mills, C. M., & McCulloch, K. J. (1998). Treatment effects of the twin block appliance: a cephalometric study. American Journal of Orthodontics and Dentofacial Orthopedics, 114(1), 15-24.
21. Illing, H. M., Morris, D. O., & Lee, R. T. (1998). A prospective evaluation of Bass, Bionator and Twin Block appliances. Part I-The hard tissues. The European Journal of Orthodontics, 20(5), 501-516.
22. Mills, C. M., & McCulloch, K. J. (2000). Posttreatment changes after successful correction of Class II malocclusions with the twin block appliance. American Journal of Orthodontics and Dentofacial Orthopedics, 118(1), 24-33.
23. McDonagh, S., Moss, J. P., Goodwin, P., & Lee, R. T. (2001). A prospective optical surface scanning and cephalometric assessment of the effect of functional appliances on the soft tissues. The European Journal of Orthodontics, 23(2), 115-126.
24. Nelson, C., Harkness, M., & Herbison, P. (1993). Mandibular changes during functional appliance treatment. American Journal of Orthodontics and Dentofacial Orthopedics, 104(2), 153-161..
25. Morris, D. O., Illing, H. M., & Lee, R. T. (1998). A prospective evaluation of Bass, Bionator and Twin Block appliances. The European Journal of Orthodontics, 20(6), 663-684.
26. Illing, H. M., Morris, D. O., & Lee, R. T. (1998). A prospective evaluation of Bass, Bionator and Twin Block appliances. Part I-The hard tissues. The European Journal of Orthodontics, 20(5), 501-516.
27. Baysal, A., & Uysal, T. (2014). Dentoskeletal effects of Twin Block and Herbst appliances in patients with Class II division 1 mandibular retrognathy. European journal of orthodontics, 36(2), 164-172..
28. Karacay, S., Akin, E., Olmez, H., Gurton, A. U., & Sagdic, D. (2006). Forsus nitinol flat spring and Jasper jumper corrections of Class II division 1 malocclusions. The Angle Orthodontist, 76(4), 666-672.
29. DerSimonian, R., & Laird, N. (2015). Meta-analysis in clinical trials revisited. Contemporary clinical trials, 45, 139-145.
30. Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta.analysis. Statistics in medicine, 21(11), 1539-1558.
31. Sterne, J. A., Becker, B. J., & Egger, M. (2005). The funnel plot. Publication bias in meta.analysis: Prevention, assessment and adjustments, 73-98.

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Assessing Cervical Spine Curvature in Skeletal Malocclusion using a Modified Cephalometric Angle

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Abstract: ***This study investigates the relationship between and skeletal malocclusion using a modified cephalometric angle. A total of 215 subjects were categorized into skeletal Class I, Class II, and Class III malocclusions. Lateral cephalograms were were traced manually, and a cervical angle was measured between the cranial base and cervical vertebrae. Results showed Class II patients had reduced cervical curvature, while Class III showed increased lordosis. A statistically significant correlation was found between the cervical spine posture and skeletal malocclusion These findings underscore the clinical value of incorporating cervical posture analysis into orthodontic assessment and treatment planning.***

Keywords: Cervical spine curvature; cephalometric analysis; skeletal malocclusion; cranio-cervical posture; orthodontic diagnosis

1. Introduction

The alignment and posture of the cervical spine have long been recognized as crucial factors in the development and function of the craniofacial complex. Cervical lordosis—a natural anterior curvature of the cervical spine—is essential for maintaining postural balance and enabling optimal neuromuscular coordination between the head and neck. Deviations from normal curvature can disrupt musculoskeletal balance but also affect dental occlusion and craniofacial growth patterns.[1]

It is well established that poor posture of the head and neck is a major contributing factor to myofunctional disorders in the craniofacial region. During the critical stages of growth, especially adolescence, abnormal cervical posture can disrupt normal craniofacial development.[2] This disruption is due to the biomechanical and anatomical connections between the neck muscles, vertebrae, and the structures of the face and jaw. The cervical spine, especially its upper segments (C1 and C2), develops in close association with cranial structures and differs embryologically from the lower vertebral column. Such developmental proximity underscores the potential for structural changes in the cervical region to influence craniofacial morphology.[3]

Epidemiological data supports this anatomical relationship. Several studies have shown a higher prevalence of craniomandibular disorders (CMD) in patients suffering from cervical spine issues. These patients often exhibit clinical signs of malocclusion, further suggesting a functional and anatomical correlation between cervical spine posture and the positioning of the jaws. For example, Festa et al. demonstrated a negative correlation between cervical lordosis and mandibular length in Class II malocclusion patients. This finding suggests that compensatory mechanisms in the cervical spine may develop in response to sagittal skeletal discrepancies of the jaws[4].

Solow and Tallgren have extensively reported on the interplay between craniocervical posture and facial morphology. Their studies identified a set of associations between increased craniocervical angulation and specific craniofacial traits, such as a steeper mandibular plane angle, increased lower anterior facial height, and mandibular retrognathism. These associations were more strongly related to the head's position in relation to the cervical column than to the true vertical plane. Such evidence indicates that cervical posture may not merely accompany but actively influence craniofacial growth trajectories.[5]

Further studies reinforce these findings. A study by Hosseinzadeh Nik and Janbaz Aciyabar introduced a practical method of evaluating cervical curvature using modified constructed angles in cephalometric analysis, finding a significant correlation between cervical posture and sagittal jaw position, particularly in Class II malocclusions. Likewise, Tecco et al. emphasized the importance of evaluating cervical angles in subjects with temporomandibular dysfunction (TMD), noting that altered mandibular position can influence cervical curvature and potentially contribute to cervical discomfort or pathology.[5]

Although these studies support the link between cervical posture and malocclusion, the nature of this relationship—whether causal, compensatory, or bidirectional—remains debated. Some authors argue that altered cervical posture may precede malocclusion, whereas others suggest that skeletal jaw discrepancies may lead to postural adaptations in the cervical spine.[6] Regardless of the direction of causality, the association has significant implications for orthodontic diagnosis and treatment planning. Evaluating cervical posture, particularly using simplified and reproducible angles such as the modified cervical angle, can enhance the clinician's understanding of each patient's unique craniofacial and postural dynamics.[7]

In light of this, the present study seeks to compare the modified cervical angle across patients with skeletal Class I, II, and III malocclusions. By evaluating pre- and postoperative changes in this angle, we aim to investigate how cervical spine curvature correlates with different sagittal skeletal patterns and assess whether orthodontic or orthognathic interventions lead to measurable changes in cervical posture. The modified cervical angle employed in this study offers a practical, reproducible approach to quantifying lordotic curvature on standard lateral cephalograms, allowing its application in routine clinical settings. This study aims to assess the relationship between cervical spine curvature and skeletal malocclusion using a modified cephalometric method, comparing Class I, II and III malocclusion. This research highlights the importance of integrating postural assessment into orthodontic diagnosis. It contributes to evolving perspectives on how cervical alignment affects or reflects craniofacial morphology and treatment outcomes.

2. Materials and Methods

Study Design and Sample Selection

This study was conducted as a cross-sectional cephalometric analysis. A total of 215 patients were included, each classified into skeletal Class I, Class II, or Class III malocclusion groups based on standard cephalometric criteria (primarily ANB angle and Wits appraisal). Subjects included both males and females with completed craniofacial growth, no prior orthodontic or surgical treatment, and no systemic or craniofacial syndromes.

Inclusion Criteria

- Fully erupted permanent dentition
- Completed craniofacial skeletal growth (ages 18–30)
- Clear lateral cephalometric radiographs taken in natural head position (NHP)
- No prior orthodontic, orthognathic, or orthopedic treatment

Exclusion Criteria

- Presence of craniofacial syndromes or deformities
- Temporomandibular joint disorders (TMD)
- History of trauma to head or neck
- Evidence of upper airway obstruction or adenoid pathology

<u>Cephalometric Measurements</u>

Lateral cephalograms were obtained in standardized conditions using a cephalostat, with the patient in natural head posture. All radiographs were traced manually by the principal investigator to ensure uniformity. The maxillomandibular skeletal relationships were assessed using traditional and postural cephalometric landmarks.

<u>Landmarks and Planes Used:</u>

- **Nasion (N):** Anterior point of the frontonasal suture
- **Sella (S):**Center of the sella turcica
- **Point A (A):** Deepest point on the contour of the premaxilla
- **Point B (B):** Deepest point on the anterior contour of the mandible
- **Posterior border of the foramen magnum**
- **Midpoints of inferior borders of cervical vertebrae (typically C2 to C4)**
- **Perpendicular bisector** of the line connecting the anterior and posterior border of the foramen magnum

Modified Cervical Angle Measurement:

To evaluate the cervical curvature, a **modified cervical angle** was constructed by:

1) Drawing a reference line along the base of the skull at the entrance to the foramen magnum.
2) Constructing a second line connecting the midpoints of the inferior borders of cervical vertebrae (C2–C4).
3) Measuring the angle formed between these two lines—representing the **inclination of the cervical column relative to the cranial base**.

This modified approach was adapted from the methods described by Hosseinzadeh et al. and Solow et al., with minor

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refinements to enhance reliability and simplicity for clinical use.

All tracings and angle measurements were performed twice, two weeks apart, to assess intra-observer reliability. The average of the two readings was used for statistical analysis.

Data Analysis:
Data was analyzed using SPSS version 19.0 (Statistical Package for Social Sciences Chicago Inc). Descriptive statistics were computed for all variables. One way ANOVA was used to compare correlation between skeletal malocclusion and cervical spine curvature using a modified cephalometric measurement technique in different skeletal groups. Correlation of cervical posture with different skeletal malocclusions was tested using Pearson's correlation. Level of significance was set at $p \leq 0.05$.

3. Results

There were 215 patients in the entire sample which were divided into Skeletal Class I, Skeletal Class II, and Skeletal Class III based on the angle ANB angle and Wits appraisal.

Table 1: Shows a Correlation between Malocclusion and point X and Y

Malocclusion	R	P
Point X	0.38	0.02
Point Y	-0.36	0.03

Test applied Spearman's Correlation
Level of significance set at $p \leq 0.05$*

Eligibility Criteria
All studies were assessed for eligibility using the PICO model, which stands for:

- (P)Patients diagnosed with malocclusion without a history of orthodontic treatment were included.
- (I) Not applicable.
- (C) The control group consisted of individuals with Class I malocclusion (normal sagittal jaw relationship) to evaluate the association of cranio-cervical posture with Class II and III malocclusion.
- (O) Outcome measures included craniovertical angles, cervicohorizontal angles, craniocervical angles, and cervical curvature obtained through cephalometric analysis.

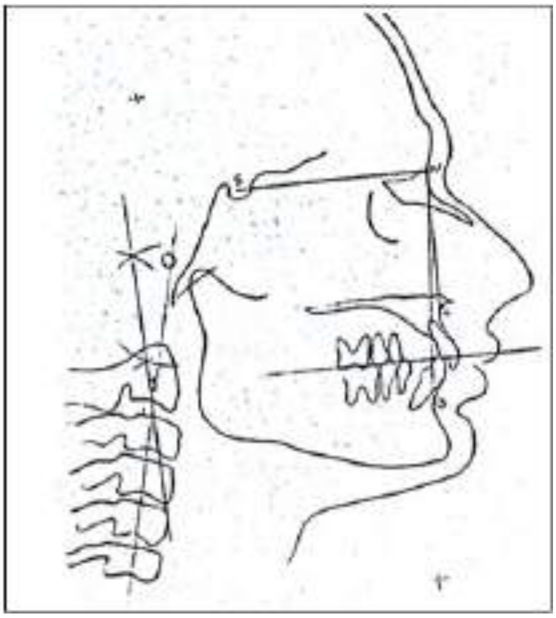
Table 2: Shows the intergroup comparison of points. Table 1 presents a comparison of points X and Y and cervical posture in the different skeletal groups. Cervical curvature was found to differ in the three classes of malocclusion, namely skeletal Class I, II and III.

		N	Mean	Std. Deviation	f-Value	p-Value
X	Class 1	71	150.4085	9.13795	31.53	0.01*
	Class 2	74	149.5811	9.26476		
	Class 3	70	158.8000	2.08931		
Y	Class 1	71	28.4930	10.71431	24.44	0.01*
	Class 2	74	30.4189	9.26476		
	Class 3	70	21.2000	2.08931		
SNA	Class 1	71	81.6056	2.48699	3.02	0.01*
	Class 2	74	82.2297	2.06436		
	Class 3	70	81.3571	2.02188		
SNB	Class 1	71	78.9014	2.74203	84.05	0.01*
	Class 2	74	78.8784	2.02012		
	Class 3	70	84.0429	3.31197		
ANB	Class 1	71	2.7183	.88128	18.14	0.01*
	Class 2	74	3.8649	1.31716		
	Class 3	70	3.6286	1.35317		

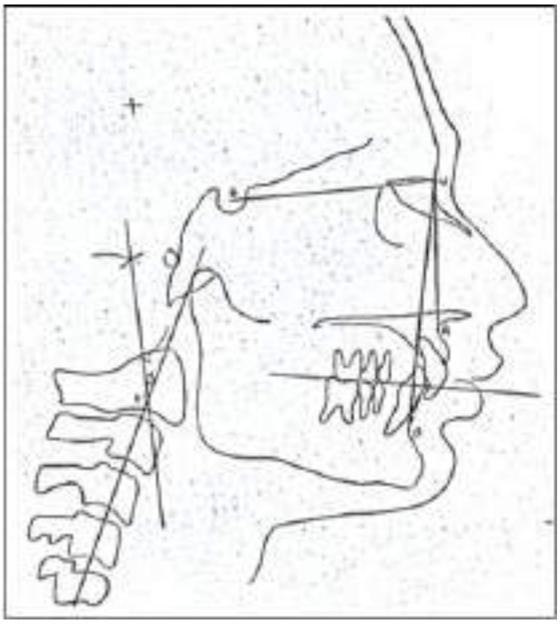
Test applied One WAY ANOVA Test
Level of significance set at $p \leq 0.05$*

Skeletal class I, class II, and class III malocclusion subjects exhibit different body postures, and there is a favorable link between cervical spine curvature and skeletal malocclusion in these subjects. Cervical curvature in subjects with Skeletal Class I base was found to be significantly different from that of Class II and Class III. Statistically significant difference was seen between cervical curvature of skeletal Class I, skeletal Class II and skeletal Class III. Skeletal class presented a weak but significant correlation with only cervical spine curvature.

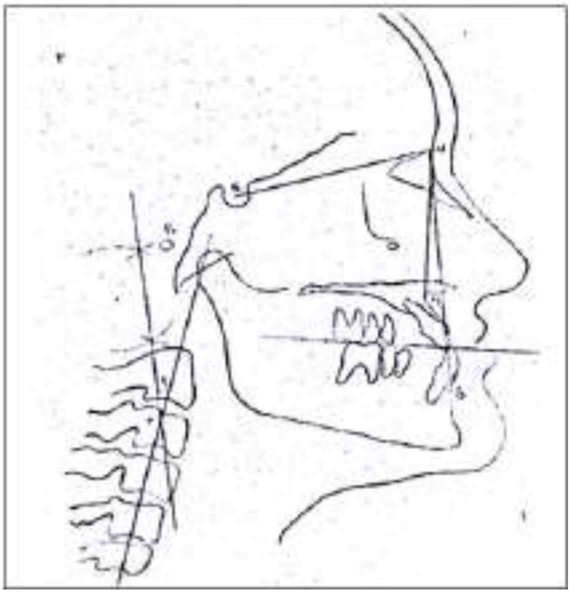
Skeletal Class I Malocclusion



Skeletal Class II Malocclusion



Skeletal Class III Malocclusion



4. Discussion

The current study was conducted in order to discover whether there was a correlation between cervical spine curvature and sagittal skeletal relation. The current study used quantitative cephalometric data to identify cervical spine curvature, in contrast to other research by Solow B and Deda MR that only used visual assessment of cervical posture. As a result, the outcomes were more accurate and dependable.

According to our study's descriptive findings, skeletal Class II patients often exhibited smaller modified cervical angles than skeletal Class I and skeletal class III subjects. This suggested that the cervical spine curvature was inclined forward. Conversely, skeletal Class III participants exhibited relatively wider modified cervical angles, which are indicative of a cervical spine curvature that is inclined backward. However, a statistically significant difference was discovered when the cephalometric measures for cervical inclinations in various malocclusions were compared.

The first writers to show a positive association between body posture and craniofacial shape were Solow and Tallgren[5]. This school of thought gained a new dimension in 1977 when Solow and Kreinborg[8] proposed the soft tissue stretch theory. According to the biomechanical concept hypothesis of postural collapse,[9] the dentition serves as the primary structural component that supports the skull. Any harm to this dental unit may cause a number of changes that ultimately lead to the collapse of the postural system.

The cervical posture of adolescents with class I, II, and III malocclusions was assessed by Garcia et al[10] in 2012, and they discovered a significant difference between the three classes. The cranium's angle with respect to the cervical spine is represented by the posterior inferior angle, which typically ranges from 101° on average to 5° with extension and extension. In the present study the posterior inferior angle was found to bewithin the normal limits for subjects in class I. But in class II, the angle was found to be smaller, indicating that the subjects posed with their necks extended forward.Class III patients had a rearward extension of the neck in their stance, as evidenced by an increase in the posterior inferior angle relative to the normal. This was consistent with the Rocabado et al investigation.[11,12]

Compared to class I subjects, it was found that the cervical curvature was lower in skeletal class III individuals and higher in class II skeletal basis subjects. This was consistent with earlier research by Nobili et al. and D'Attilio,[13,14] which found that individuals with class III skeletal malocclusions exhibited a backward posture whereas those with class II malocclusions had a forward posture.

The chain theory provides an explanation for the class II malocclusion group's forward sway and the class III malocclusion group's backward sway. This hypothesis divides the entire body system into three rings. The head, neck, and TMJ muscles made up the upper ring, the back and vertebrae muscles made up the middle ring, and the foot, ankle, and leg muscles made up the lower ring. The three rings must be in perfect harmony and synchronization for a body to function. Modifications in the other two rings would result from any disruption in one of the rings.In a similar vein, individuals with class III malocclusion had a backward head posture, which caused the first ring to be positioned backward. This caused the second ring to move more forward, and the third ring to go backward.[16]

The soft tissue stretching hypothesis, put forth by Solow and Kreinborg in 1998, offers yet another explanation for the relationship between malocclusion and posture[9]. D'Attilio et al[15] assessed the cervical posture of 120 kids and found that the two main factors causing the posture change were mandibular size and position. These two elements then affect the neural-muscular system, which alters neck posture and, ultimately, body posture. Research assessing postural alterations following orthognathic surgery has shown that there is a lasting postural change; nevertheless, within a year, the neck posture returned to its pre-operative state.[17] This raises the question of whether malocclusion affects posture.

The cervical spine may be uprighting or straightening if the middle cervical inclination increases and the higher cervical inclination decreases. Studies by Kamal and Fida,[18] Krishna et al[19]and Smailiene et al[20] that documented cervical spine uprighting using a Twin Block appliance, corroborated this. In terms of anatomy, the middle and lower cervical spines encircle the oropharynx and hypopharynx, while the upper cervical spine borders the nasopharynx. The slight alterations in nasopharyngeal airway observed with functional appliance treatment are associated with a decrease in upper cervical inclination. According to other systematic reviews, the increase in oropharynx and hypopharynx with functional appliance treatment is associated with the increase in middle cervical inclination observed in the review by Murali S.[21]

It's critical to comprehend how a functional appliance affects the cervical spine. Cervical hyperlordosis can be managed with the use of functional appliances when the cervical lordosis angle decreases as a result of treatment. Although mouth appliances have been used to treat orofacial discomfort and obstructive sleep apnea, their potential for treating postural disorders of the cervical spine has not yet been investigated. The systematic review by Murali S emphasized

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the possible use of functional appliances in the treatment of cervical spine alignment and hyperlordosis[21].

This study found that the cervical spine curvature of the subjects with class I malocclusion were normal. It was discovered that the forward cervical position were present in subjects with class II malocclusion. And also subjects with class III skeletal malocclusion exhibited a backward cervical position.

Changes in posture can result in a number of issues. Patients with postural collapse have been known to experience persistent headaches, back discomfort, nerve compressions, and other symptoms.[22]The biomechanical concept theory of postural collapse explains the mechanism by which malocclusion causes postural collapse[23]. This also explains the necessity of correcting any postural changes as soon as possible, most likely in the younger age group, in order to prevent further deformations, maximize the use of the musculoskeletal system's existing functional efficiency, and take advantage of physiological growth spurts.

5. Conclusion

This study confirms a correlation between cervical spine curvature and skeletal malocclusion classes. Class I individuals displayed near-normal posture, while class II subjects exhibited forward cervical inclination and class III subjects showed posterior tilting. These variations highlight the relevance of cervical assessment in orthodontic diagnosis. Early intervention addressing both malocclusion and posture could improve treatment outcomes and overall musculoskeletal harmony.

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References

[1] Patel PD, Arutyunyan G, Plusch K, Vaccaro A Jr, Vaccaro AR. A review of cervical spine alignment in the normal and degenerative spine. J Spine Surg. 2020 Mar;6(1):106-123.
[2] Dipalma G, Inchingolo AD, Pezzolla C, Sardano R, Trilli I, Di Venere D, Corsalini M, Inchingolo F, Severino M, Palermo A, Inchingolo AM. Head and Cervical Posture in Sagittal Skeletal Malocclusions: Insights from a Systematic Review. J Clin Med. 2025 Apr 11;14(8):2626.
[3] Alvi MA, Moghaddamjou A, Fehlings MG. Anatomy and physiology of cervical spine and cervical spinal cord. InDegenerative Cervical Myelopathy 2023 Jan 1 (pp. 11-33). Academic Press.
[4] Peng H, Liu W, Yang L, Yan P, Zhong W, Gao X, Song J. Craniocervical posture in patients with skeletal malocclusion and its correlation with craniofacial morphology during different growth periods. Scientific Reports. 2024 Mar 4;14(1):5280.
[5] Tecco S, Festa F. Cervical spine curvature and craniofacial morphology in an adult Caucasian group: a multiple regression analysis. Eur J Orthod. 2007;29(2):204-9.
[6] Peng H, Liu W, Yang L, Zhong W, Yin Y, Gao X, Song J. Does head and cervical posture correlate to malocclusion? A systematic review and meta-analysis. PLoS One. 2022 Oct 25;17(10):e0276156.
[7] Kumar S, Nandy A, Bajjad AA, Das K. Soft tissue paradigm in orthodontic diagnosis and treatment planning.
[8] Solow B, Tallgren A. Head posture and craniofacial morphology. American Journal of Physical Anthropology. 1976; 44(3):417-435.
[9] Solow B, Kreiborg S. Soft-tissue stretching: a possible control factor in craniofacial morphogenesis. European Journal of Oral Sciences. 1977; 85(6):505-507.
[10] Matsaberidze T, Conte M, Quatrano V. Conception of Human Body Biomechanical Balance, Metacognitive Diversity, Interdisciplinary Approach. Int J Oral Health Dent Manag. 2018; 2(1):1-6.
[11] García, N.; Sanhueza, A.; Cantín, M. & Fuentes, R. Evaluation of cervical posture of adolescent subject in skeletal class I, II, and III. Int. J. Morphol., 30(2):405 - 410, 2012.
[12] Rocabado M. Biomechanical relationship of the cranial, cervical, and hyoid regions. J Craniomandibular Pract. 1983 Jun-Aug; 1(3):61-6. 32.
[13] Phillips C, Snow M, Turvey T, Pro□t W. The effect of orthognathic surgery on head posture. The Eur J Orthod 1991; 13(5):397-403.
[14] Nobili A, Adversi R. Relationship between posture and occlusion: a clinical and experimental investigation. Cranio 1996; 14: 274–85
[15] D Attilio M, Epifania E, Ciuffolo F, Salini V, Filippi MR, Dolci M, et al. Cervical lordosis angle measured on lateral cephalograms; □ndings in skeletal class II female subjects with and without TMD: a cross sectional study. Cranio. 2004; 22:27-44.
[16] Pradeep S, Venkatasubramanian P, Parameswaran R, Vijayalakshmi D. Quantitative analysis of body posture and its correlation with cervical posture in various malocclusions. 2021
[17] Aglarci C. Evaluation of cervical spine posture after functional therapy with twin-block appliances. J Orthod Res 2016; 4:8-12
[18] Kamal AT, Fida M. Evaluation of cervical spine posture after functional therapy with twin-block appliances: a retrospective cohort study. Am J Orthod Dentofacial Orthop. 2019 May;155(5):656–661.
[19] Krishna SSS, Shashikumar B, Naik RD. Evaluation and comparison of cervical spine posture in class II division I patients treated with twin block appliances, Forsus appliances, and bilateral sagittal split osteotomy: a cephalometric study. Contemp Clin Dent. 2023;14(2):157–165.
[20] Smailien˙ e D, Intien˙ e A, Dobradziejut˙ e I, Kuˇsleika G. Effect of treatment with twinblock appliances on body posture in class II malocclusion subjects: a prospective clinical study. Med Sci Mon Int Med J Exp Clin Res. 2017;23:343–352.
[21] Murali S, Kannan A, Kailasam V. Cervical spine changes with functional appliance treatment: A systematic review and meta-analysis. Journal of Oral Biology and Craniofacial Research. 2024 Jul 1;14(4):446-54.
[22] Rocabado M, Johnston B E, Blakney M G 1982 Physical therapy and dentistry: an overview. Journal of Craniomandibular Practice 1: 46 – 49

[23] Matsaberidze T, Conte M, Quatrano V. Conception of Human Body Biomechanical Balance, Metacognitive Diversity, Interdisciplinary Approach. Int J Oral Health Dent Manag. 2018; 2(1):1-6.

ORIGINAL RESEARCH PAPER

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EVALUATION OF MATRIX METALLOPROTEINASE-9(MMP -9) IN GINGIVAL CREVICULAR FLUID AND SALIVA IN RELATION TO ORTHODONTIC TOOTH MOVEMENT: A SYSTEMATIC REVIEW.

Orthodontics

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ABSTRACT

Background: Matrix metalloproteinase-9 (MMP-9) plays a crucial role in extracellular matrix remodeling and periodontal changes during orthodontic tooth movement (OTM). Understanding its expression in gingival crevicular fluid (GCF) and saliva can provide insights into the biological response to orthodontic forces. **Objective:** This systematic review aims to evaluate the levels of MMP-9 in GCF and saliva during orthodontic treatment, examining its correlation with different phases of tooth movement and treatment modalities. **Methods:** A comprehensive search was conducted in PubMed, Scopus, and Google Scholar following the PRISMA guidelines. Studies assessing MMP-9 levels in saliva and GCF during orthodontic treatment were included. Quality assessment was performed using the ROB-2 tool for RCTs. **Results:** The included studies demonstrated a significant increase in MMP- 9 levels following the application of orthodontic force, with peak concentrations observed at different time points. Some studies highlighted variations in MMP-9 expression between extraction and non-extraction groups, as well as differences based on age andtreatment phase. The use of low-intensity laser therapy (LILT) was found to modulate MMP-9 expression, potentially enhancing the rate of tooth movement. **Conclusion:** MMP-9 serves as a potential biomarker for monitoring biological responses during orthodontic treatment. Its level in GCF and saliva reflect periodontal remodelling and may guide personalized orthodontic approaches. Future research should focus on standardizing sampling techniques and exploring therapeutic interventions to optimize treatment outcomes.

KEYWORDS

Orthodontic tooth movement, gingival crevicular fluid, saliva, PRISMA, RCT, low-intensity laser therapy.

INTRODUCTION

Orthodontic tooth movement (OTM) involves the coordinated response of the periodontium, including the gingiva, periodontal ligament (PDL), cementum, and alveolar bone. The PDL, a vascular connective tissue, is the first to respond to orthodontic forces, initiating extracellular matrix (ECM) remodeling and alveolar bone adaptation[1]. Within hours of force application, PDL thickness changes, and inflammatory responses activate matrix metalloproteinases (MMPs), leading to collagen degradation and ECM reorganization[2] .The compression–tension theory, the most widely accepted explanation of orthodontic tooth movement(OTM), suggests that cellular responses in the periodontal ligament and alveolar bone are modulated by chemical messengers released from blood flow or cells in situ in response to mechanical stress[3].Orthodontic forces induce strain in the periodontium, creating compression and tension zones in the PDL. These zones lead to bone resorption in compression areas and bone formation in tension areas, ultimately resulting in tooth movement[4].Gingival fibroblasts also contribute to bone remodeling by regulating collagen synthesis and MMP activity [5]In the alveolar bone, osteoclasts appear within 30–40 hours at compression sites, while osteoblasts facilitate bone deposition at tension sites, ensuring balanced remodeling[6].

The desire to accelerate OTM has long been a goal for orthodontists and patients, as it could reduce treatment duration and minimize adverse effects such as pain, discomfort, periodontal diseases, dental caries, and iatrogenic damage like root resorption[7]. One of the key factors modulating OTM is the activity of MMPs, particularly MMP-9, in the gingival crevicular fluid (GCF) at the pressure side of the PDL. MMP-9, also known as gelatinase B, plays a critical role in ECM degradation, specifically in the breakdown of gelatin and type IV collagen, which are major components of basement membranes[8–10].MMP-9 is involved in various physiological and pathological processes, including tissue remodeling, wound healing, inflammation, and cancer progression[3, 11] . Itis primarily produced by polymorphonuclear leukocytes (PMNs), epithelial cells, and oral keratinocytes[12] and its expression is induced by inflammatory stimuli, cytokines, and growth factors [13]. MMP-9 activity is regulated at multiple levels, including geneexpression, secretion as an inactive proenzyme, and activation by proteolytic cleavage[3]. Tissue inhibitors of metalloproteinases (TIMPs), particularly TIMP- 1, play a crucial role in controlling MMP-9 activity by binding to both active and pro-MMP-9 [10].

In normal conditions, MMP levels are low, but their expression is elevated in inflamed tissues or those undergoing remodeling, such as during orthodontic treatment [13,14].Orthodontic forces trigger an aseptic inflammatory response characterized by vascular changes and inflammatory cell infiltration [15]. MMPs are key regulators of extracellular matrix remodeling during orthodontic treatment, with their expression being influenced by mechanical stress, biological mediators, and inhibitors. Several studies have investigated the effect of orthodontic forces on MMP production. The objective of this current systematic review is to evaluate the role of MMP-9 in gingivalcrevicular fluid (GCF) and saliva during orthodontic treatment, focusing on their regulation, site-specific expression, and potential therapeutic modulation to better understand their impact on orthodontic tooth movement (OTM).

MATERIALAND METHODS:

Protocol And Registration

This systematic review was conducted and performed according to the preferred reporting items for systematic review and meta-analysis (PRISMA) statement[16]After searching for previously registered similar studies, the Review protocol of this Systematic review was registeredregistered in Prospective Registration of Systematic Review (PROSPERO)(CRD42024609046).

Literature Search

A comprehensive electronic search was performed till December 2024for the studies published within the last 34 years (from 1990 to 2024) using the following databases: PubMed, Google Scholar and Scopus to retrieve articles in the English language. The searches in the clinical trials database, cross- referencing and grey literature were conducted using Google Scholar, Greylist and OpenGrey.

Initial search in PubMed ws done using the search strategy: "orthodontic*"[All Fields] AND ("saliva"[MeSH Terms] OR "saliva"[All Fields] OR "salivas"[All Fields] OR "saliva s"[All Fields] OR "GCF"[All Fields] OR "Gingival crevicular fluid"[All Fields]) AND ("MATRIX METALLO PROTEINASE 9"[All Fields] OR "mmp 9"[All Fields]). In addition to the electronic search, a hand search was also made, and reference lists of the selected articles werescreened. The reference lists of identified studies and relevant reviews on the subject were also scanned for possible additional studies.

Study Selection And Eligibility Criteria:

Does the level of Matrix Metalloproteinase 9 (MMP-9) in gingival crevicular fluid (GCF) and saliva change in response to orthodontic tooth movement, and how does it correlate with different phases of orthodontic treatment. Inclusion and exclusion criteria were determined (Table1). After the removal of duplicates, articles were screened based on title, abstract, and full text. When the decision on the basis of title and abstract was inconclusive, the full-text article was acquired. When an identical study was published in more than one language, the English publication was considered.

Eligibility Criteria

Inclusion Criteria

- **Population:** Human participants undergoing orthodontic treatment with fixed or removable appliances.
- **Intervention :** Assessment of MMP-9 levels in gingival crevicular fluid (GCF) and/or saliva in response to orthodontic tooth movement.
- **Comparator:** Studies comparing MMP-9 levels before, during, or after orthodontic treatment or between different phases of tooth movement.
- **Outcome:** Studies reporting quantitative changes in MMP-9 levels in GCF and/or saliva during orthodontic tooth movement.

Exclusion Criteria

Animal or in vitro studies., Individuals not undergoing orthodontic treatment. Studies assessing biomarkers other thanMMP-9. Studies evaluating MMP-9 in conditions unrelated to orthodontictooth movement. Studies without a comparative analysis of MMP-9 levels in different treatment phases.

Studies withoutspecific data on MMP-9 levels.Studies withincomplete orinsufficient dataregarding MMP-9 andorthodontic treatment. Systematic reviews, meta-analyses, editorials, and casereports. Studies published in languages other than English.

Screening Process

Following the electronic search, all citations found were compiled and uploaded to Covidence, and duplicates were removed. Both titles and abstracts were evaluated by two investigators. In the event of ambiguity, the full text was read for a joint decision. The full texts of the abstracts that were screened were obtained and evaluated for eligibility. Any disagreement about whether a study should be included was discussed between the two reviewers until a mutual agreement was reached or a third reviewer was approached.Quality assessment of included studies

The quality of included studies was assessed using ROBINS-I (Risk Of Bias In Non-randomized Studies -of Interventions) It examines seven domains: bias due to confounding, bias in selection of participants, bias in classification of interventions, bias due to deviations from intended interventions, bias due to missing data, bias in measurement of outcomes, andbias in selection of the reported result. Each domain is rated as low, moderate, serious, or critical risk, guiding the overall judgment of a study's internal validity.

Data Collection Process And Dataitems

The PRISMA flow diagram outlines the stepwise process of study selection in a systematic review. It begins with the identification phase, where records were retrieved from database searches (162 studies) and additional sources (2 studies). After removing duplicates, 127 records remain for screening. In the screening phase, titles and abstracts were reviewed, and 97 records were excluded for not being relevant to the research question. The remaining 30 full- text articles were assessed for eligibility based on predefined inclusion and exclusion criteria.

During the eligibility phase, 21 articles were excluded as they did not meet the inclusion criteria, leaving 9 studies for inclusion in the qualitative synthesis.

These final selected studies contribute to the systematic review by providingdata for further analysis. The PRISMA diagram ensures transparency in the study selection process, helping researchers maintain a standardized approach while minimizing bias in systematic reviews and meta-analyses. (Figure 1.PRISMA flow diagram).

Assessment Of Methodological Quality Of Included Studies

The risk of bias assessment using the ROBINS-I tool (Figure 2) evaluates several domains across nine studies. Most studies demonstrated a low risk of biasacross multiple domains, particularly in D3 (bias in classification of interventions), D4 (bias due to deviations from intended interventions), and D7 (bias in selection of the reported result). However, moderate riskswere noted frequently in domains such as D1 (bias due to confounding), D2 (selection of participants), D5 (missing data), and D6 (measurement of outcomes). Notably, the studies byRody et al. (2013), Bildt et al. (2009), Capelli et al. (2011), Jivrajani et al., and Alikhani et al. (2017) showed consistently low risk across almost all domains, suggesting higher methodological rigor. In contrast, Suriln et al. (2014), Xu et al. (2020), and Lin et al. (2021) exhibited moderate risk in several areas, particularly in confounding and measurement domains, leading to an overall moderate risk of bias.

The bar graph (Figure 3) provides a summary of the distribution of risk of bias across the seven domains assessed using the ROBINS-I tool, along with theoverall risk of bias. It is evident that bias due to missing data and bias in measurement of outcomes show the highest proportion of moderate risk among the domains, indicating these as the most common sources of bias across the included studies. Bias due to confounding, selection of participants, and deviations from intended interventions also exhibit a notable proportion of moderate risk, though to a slightly lesser extent. In contrast, bias in classification of interventions and bias in selection of the reported resultare predominantly rated as low risk. [33]

RESULTS:

Study Selection

The search strategy resulted in 164 articles. A total of 134 records were excluded on the basis of screening of title and abstract. The full texts of 30 articles were obtained and assessed for eligibility. Respecting all selection phases based on the eligibility criteria, 9 articles qualified for final analysis. Figure 1 displays the different steps of the selection process entered in PRISMA flow chart.Study Characteristics

From Table 2 we can conclude that the participants in the studies were generally healthy individuals with no history of periodontal disease or systemic conditions that could affect orthodontic outcomes. Age groups varied across studies, with some including adolescents [17] and others focusing on both adolescents and adults (e.g., Alikhani et al.,) [26]. Exclusion criteria commonly included the use of medications such as antibiotics, anti-inflammatory drugs, and corticosteroids, as well as smoking and pregnancy.

Intervention

Orthodontic movement was the primary intervention across all studies, with different methodologies such as canine retraction, fixed appliance placement, and comparisons between extraction and non-extraction groups. Some studies, like Jivrajani et al.[19], investigated additional interventions such as LILT to assess its effect on MMP-9 expression and the rate of tooth movement.

Total Sample

Sample sizes varied across studies, ranging from small cohorts of 8-20 participants to larger groups of over 100 participants. Most studies had a balanced distribution of male and female participants.Mean Age Group

The mean age of participants ranged from early adolescence to adulthood. Studies such as Xu et al[19] had an average age of 21-22 years, while others like Lin et al. [21] [26]focused on younger subjects aged 12-18 years. Alikhani et al. included both adolescents (mean age 13.3 years) and adults (mean age 31 years), allowing for comparisons based on age-related differences in orthodontic responses.

Sample Collected

Of the 9 studies 7 studies collected gingival crevicular fluid (GCF) and in 2 studies saliva was collected at various time points before, during, and after orthodontic force application. Sampling schedules varied, with some studies[21] collecting GCF at multiple intervals ranging from baseline to 12 weeks post- treatment. Xu et al[19] collected saliva at four time points, including pre- and post- orthodontic appliance placement, to analyze MMP concentrations.

The results from the included studies consistently demonstrated the impact of orthodontic tooth movement on matrix metalloproteinase-9 (MMP-9) levels in gingival crevicular fluid (GCF) and saliva. Several studies confirmed a significant increase in MMP-9 levels following the application of orthodontic force, with peak concentrations varying across different time points. This indicates that MMP-9 coul d serve as a valuable biomarker for assessing the biological response to orthodontic treatment. Additionally, studies comparingextraction and non-extraction groups (Xu et al.,)[19] found that orthodontic forces modulated salivary MMP levels, reinforcing the role of these enzymes in tooth movement.

Age-related differences were another key finding across multiple studies. Alikhani et al. [26] found that adults exhibited higher levels of cytokines and osteoclastic activity in response to orthodontic forces compared to adolescents. However, despite the increased biological response, adults experienced slower tooth movement, suggesting that age influences the rate and intensity of the orthodontic response. Similarly, Rody et al. [22] observed no significant changes in MMP-9 levels over time, indicating variability in individual responses to orthodontic forces.

The effect of external interventions was also explored in some studies. Jivrajani et al. [25]investigated the impact of Low-Intensity Laser Therapy (LILT) and found that it increased MMP-9 concentrations in GCF, suggesting a potential role for LILT in enhancing orthodontic treatment outcomes.

Additionally, Capelli et al. [24] demonstrated that MMP levels were significantly modulated at the compression side of the tooth, further confirming the role of MMPs in periodontal remodeling during orthodontic movement.

The methods of sample collection varied across studies, with GCF and salivabeing the primary sources for biomarker analysis. Studies utilizing GCF sampling (Lin et al., ; Bildt et al.,) [21, 24] provided more localized insights into periodontal responses, while saliva-based studies (Xu et al.,) [18] offered a non-invasive method for monitoring systemic changes. Both methods demonstrated that MMP- 9 levels fluctuated in response to orthodontic forces, suggesting their potential use in clinical assessments.

Overall, the studies confirm that orthodontic forces induce significant biochemical changes, particularly in MMP-9 expression, which plays a critical role in periodontal remodeling. The findings underscore the importance of considering patient-specific factors such as age, intervention strategies, and biomarker sampling techniques in optimizing orthodontic treatment. Future research should focus on longitudinal studies with larger sample sizes to establish standardized protocols for monitoring orthodontic responses using MMP biomarkers.

Reason For Not Conducting A Meta-analysis

A meta-analysis was not performed due to the substantial heterogeneity across the included studies. The variations in study design, sample collection methods (gingival crevicular fluid vs. saliva), time points for MMP-9 measurement, orthodontic treatment protocols (fixed appliances, extractions, and non- extractions), and analytical techniques made it challenging to pool the datameaningfully. Additionally, the differences in statistical reporting, outcome measures, and study populations further limited the ability to generate a standardized effect estimate. Given these inconsistencies, a qualitative synthesis was deemed more appropriate to summarize the findings and provide a comprehensive overview of the role of MMP-9 in orthodontic tooth movement.

DISCUSSION:

The findings from the reviewed studies indicate that matrix metalloproteinase- 9 (MMP-9) plays a crucial role in orthodontic tooth movement (OTM) and periodontal remodeling. Several studies have shown a significant upregulation of MMP-9 in gingival crevicular fluid (GCF) and saliva following the application of orthodontic forces, suggesting its involvement in the extracellular matrix degradation necessary for tooth movement.

MMP-9 and Orthodontic Tooth Movement

The pattern of MMP-9 expression varies across studies. For instance, Surlin et al [17] observed an increase in MMP-9 levels, peaking at 8 hours and remaining elevated for up to 72 hours post-activation. Similarly, Lin et al [3] found that MMP-9 levels were significantly upregulated between 24 hours and 4 weeks after the application of orthodontic force, returning to baseline levels by 12 weeks. These findings suggest that MMP-9 is an early biomarker of orthodontic-induced tissue remodeling, potentially influencing the rate andefficiency of tooth movement.

Moreover, Xu et al[19] reported that salivary MMP-9 levels were significantly elevated in the extraction group at one hour post-orthodontic appliance fitting, highlighting a possible correlation between the magnitude of force application and MMP-9 expression. This was further supported by Sioustis et al [20], who noted a medium positive correlation between MMP-9 levels and bleeding on probing (BOP) before and after orthodontic treatment, emphasizing its role in the inflammatory response associated with orthodontic therapy.

Variability in MMP-9 Expression Across Different Study Designs

The studies included in this review exhibit variability in study design, sample collection methods, and participant characteristics. While most studies used GCF as the primary biological sample, some utilized saliva, which might have contributed to variations in reported MMP-9 concentrations. Additionally, differences in sample collection time points (e.g., immediate post-force application vs. several weeks later) further complicate direct comparisons between studies.

Rody et al [22]found no significant changes in MMP-9 levels over time, which may be attributed to differences in sample size, orthodontic force magnitude, or analytical techniques used for MMP-9 quantification.Age and MMP-9

Age-related differences emerged as a key finding in multiple studies. Alikhani et al.[26] also studied on adults and adolescents and reported that adults showed higher cytokine levels and osteoclastic activity in response to orthodontic forces than adolescents. Despite this heightened biological response, tooth movement was slower in adults, suggesting that age affects both the intensity and rate of orthodontic adaptation. Similarly, Rody et al. [22] found no significant temporal changes in MMP-9 levels, highlighting individual variability in responses to orthodontic force

Effect of external intervention and MMP-9

Interventions such as Low-Intensity Laser Therapy (LILT), as studied by Jivrajani et al., [25] have shown potential in modulating MMP-9 levels, offering a novel approach to enhancing orthodontic treatment outcomes. According to the study LILT increased the rate of orthodontic tooth movement by 38% and application of LILT increased the concentration of MMP-9 in GCF, in the initial period of orthodontic tooth movement .The changes in the application schedule for LILT were desirable as it was more effective in the earlier part of tooth movement as compared to the later part.

Site specific expression of MMP-9

According to study by Lin et al[21] The levels of MMP-9 of both tension andpressure side of the study teeth were significantly up-regulated during first 4 weeks compared and decreased to baseline level after that and for the control teeth MMP-9 at pressure and tension side .In Another study by capelli et al [24] For MMP 9 changes over time were only statistically significant at the pressure side. There was an increase in MMP-9 levels 1 hour after activation of the orthodontic appliance, followed by a sharp decrease after 1 day of tooth movement. Thereafter, there was a steady increase in GCF content of MMP 9 until the end of the observation period.

Clinical Implications

The findings suggest that MMP-9 could serve as a potential biomarker for monitoring orthodontic treatment progression and assessing individual variations in biological response. Understanding MMP-9 dynamics may also aid in optimizing orthodontic force application to minimize treatment duration and adverse periodontal effects.

Clinical, Research, And Policy Implications

Clinical Practice:

- Clinicians can leverage MMP-9 as a potential biomarker to monitor patient- specific responses to orthodontic forces, potentially allowing for personalized treatment approaches.
- Optimizing orthodontic force magnitude based on MMP-9 expression levels may help minimize adverse effects such as excessive inflammation and periodontal breakdown.

Research:

- Future studies should focus on longitudinal research with larger sample sizes to validate MMP-9 as a reliable biomarker for orthodontic treatment monitoring.
- Standardization of sampling methods (GCF vs. saliva) and analytical techniques is necessary to ensure consistency across studies.
- Investigations into the interactions between MMP-9 and other inflammatory mediators may provide a more comprehensive understanding of its role in OTM.

Policy: Funding for research on molecular biomarkers in orthodontics should be prioritized to advance precision orthodontics and improve treatment efficiency.

CONCLUSION

This systematic review examined the expression and modulation of matrix metalloproteinase-9 (MMP-9) in gingival crevicular fluid (GCF) and saliva during orthodontic treatment. Findings showed that MMP-9 levels rise significantly in response to orthodontic force, especially in the early stages of tooth movement, highlighting its role in periodontal remodeling. Higher levels were noted on the pressure side of moving teeth, indicating site-specific expression.

Therapeutic interventions like low-intensity laser therapy enhanced MMP-9 activity, and age-related differences suggested greater biological response but slower tooth movement in adults. Despite some variability across studies, MMP-9 appears to be a promising biomarker for monitoring and potentially enhancing orthodontic outcomes. Future studies should focus on standardizing methods and exploring MMP-9–based therapeutic strategies.

The reviewed studies have several limitations. There is notable heterogeneity in methodologies, including variations in sample collection, participant selection, and MMP-9 measurement, leading to inconsistent findings. Many studies also suffer from small sample sizes, limiting the generalizability of results. Additionally, short follow-up durations hinder the understanding of long-term changes in MMP-9 levels and their influence on treatment outcomes.

Legends To Illustrations And Tables –

A) Illustrations

Figure 1: Prisma Flow Diagram For The Selection Of Studies

Figure 2: Risk of Bias of the included studies

Figure 3: Overall summarative risk of bias of the studies included in the present systematic review

B) Tables

Table 1: Search Strategy Of Different Databases

Table 2: Demographic Data Of The Nine Included Studies In The Current Systematic Review

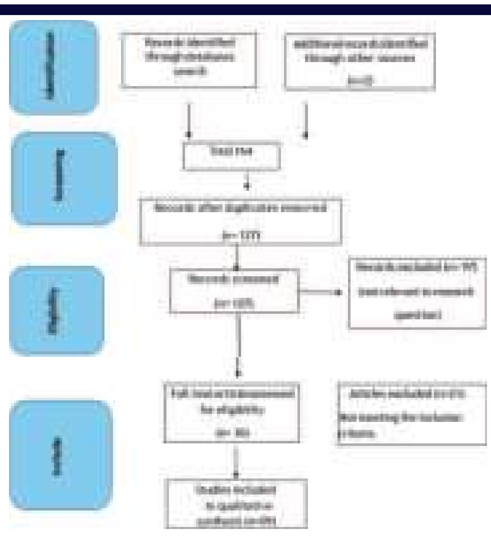

Figure.1 - PRISMA flow diagram for the selection of studies

Table 1: Search Strategy Of Different Databases

Database	Search strategy	Results
Pubmed	"orthodontic*"[All Fields] AND ("saliva"[MeSH Terms] OR "saliva"[All Fields] OR "salivas"[All Fields] OR "saliva s"[All Fields] OR "GCF"[All Fields] OR "Gingival crevicular fluid"[All Fields]) AND ("MATRIX METALLO PROTEINASE 9"[All Fields] OR "mmp 9"[All Fields])	87
Scopus	TITLE-ABS-KEY (orthodontic*) AND (saliva OR salivas OR "saliva s" OR GCF OR "gingival crevicular fluid") AND ("matrix metalloproteinase 9" OR "mmp 9")	22
Google scolar	"orthodontic" OR "orthodontics" AND ("saliva" OR "salivas" OR "gingival crevicular fluid" OR "GCF") AND ("matrix metalloproteinase 9" OR "MMP-9")	53

Table 2– Demographic Data Of The Nine Included Studies In The Current Systematic Review

Author , Year	Study design	Characteristics of the patient	Intervention	Total sample	Mean age group	Sample collected	Conclusion
Bildt et la, 2009[23]	Controlled trials in which MMP-9 level is estimated in gcf collected from resorption side and apposition side side of teeth which were orthodontically moved and around control teeth ..	Eight orthodontic patients .The following inclusion criteria were applied: no use of medication, good periodontal health .	All 8 patients had fixed appliances with superelastic nickel-titanium coil springs (GAC international Inc., Bohemia, New York, USA) that gave light continuous forces of approximately 150 cN.	Eight orthodontic patients [two males, six females]	mean 13.6 ± 2.6 years)	GCF was collected at the apposition and resorption sides of teeth that were orthodontically moved and around control teeth. The type and number of teeth differed between the patients depending on the treatment plan. In most cases, bo th upper first premolars were distalized.	More active MMP-9 was present at the resorption side of orthodontically moved teeth compared with the control (P = 0.003)

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capelli et al, 2011(24)	Controlled trial in which MMP 9 level was estimated from gcf collected from pressure and tension side of maxillary canines during retraction after first premolar extraction.	Fourteen subjects (three males and 11 females, 18.8 ± 4.8 years of age; range from 12 to 28 years) had their maxillary canines retracted Participants requiring maxillary first premolar extractions as part of their orthodontic treatment were enrolled in this study. Exclusion criteria were autoimmune diseases, pregnancy, lactation, and use of any medication that could interfere with orthodontic tooth movement.	Retraction of canines after the premolar extraction using niti springs in arch wire with 150 g force	Fourteen subjects (three males and 11 females)	18.8 ± 4.8	Samples of GCF were collected from the mesial (tension) and distal (pressure) sides of the maxillary canines of each subject at seven time points. The first collection took place 7 days before the orthodontic force was first applied (−7 days), the second was undertaken on the day of force application, denominated time 0, and third, 1 hour, the fourth, 24 hours, the fifth, two weeks, the sixth, three weeks (21 days), and the Seventh,80 days after orthodontic force was first applied	For MMP 9 changes over time were only statistically significant at the pressure side $P <$ 0.01). There was an increase in Mmp9 levels 1 hour after activation of the orthodontic appliance, followed by a sharp decrease after 1 day of tooth movement .Thereafter, there was a steady increase in GCF content of MMP 9 until the end of the observation period.
Rody et al, 2013(22)	Controlled trial in which MMP-9 levels were estimated from GCF collected from the upper incisors (experimental sites) and lower incisors (control sites) of ten adolescents and 10 adults at five time points. .	Ten adolescents (14.4 6 1.43) and 10 adults (28.5 6 7.83) with Class I malocclusions and minor upper incisor crowding were allocated to two different age groups.	Orthodontic movement(Brackets were bonded only in the upper arch over the 20-week period of the experiment.)	20 patients	Ten adolescents (14.4 6 1.43) and 10 adults (28.56 7.83)	Samples of GCF were collected from the upper incisors (experimental sites) and lower incisors (control sites) of each subject at five time points. G CF sampling was performed according to the follow ing sched ule: T0 (baseline), immediately before bonding;T1, 3 weeks after appliance placement and insertion of the first aligning archwire:	There were no statistically significant changes over time in the concentration of MMP-9between experimental and control teeth (P . .05).Also, there were no statistically significant differences in the concentration of MMP-9 collected from experimental teeth between

						T2, 6 weeks after insertion of the first archwire: T3, 6 weeks after insertion of the third arch wire: T4, 2 weeks after the last aligning archwire	adult and adolescents
Surlin et al, 2014(17)	Split mouth study in which canine distalisation was done on experimental side using laceback appliance and no force applied on contralateral side. MMP- 9 level was checked at different intervals from both sides	The patients were enrolled according to the following criteria: (1) patients in general good health, (2) with a good oral hygiene, (3) with clinically and radiological healthy periodontal tissues, (4) no therapy with antibiotics in the last 3 months, and (5) no use of anti- inflammatory drugs in the previous 30 days.	GCF samples were collected from 16 orthodontic young patients requiring upper canine distalization done with laceback appliance placed on experimental side and no force was applied on control side .	16 (10 females and 6 males)	age range 13 to 17 years, mean age 14 ± 1.67 years	, GCF samples were collected from distal side of an upper canine requiring distalization on which was lacedalace back appliance, to assess total MMP9 in GCF 1h before and after 1, 4, 8, 24, and 72 hours, 1 and 2 weeks from the tooth which is considered as test tooth (TT) and also from the contralateral canine considered as control tooth (CT) on which no force was applied.	The results obtained for the Test teeth showed an increase of GCF levels of MMP9 from 1 hour before the orthodontic appliance(−1 h as baseline level) to a maximum at 8 hours (approximately 1.6-fold compared to the baseline level), followed by a decrease reaching the value of baseline at 72 hours and stabilization starting with first week at levels higher than baseline. For control teeth levels of mmp9 was similar to the base line level of test teeth
Alikhani et al, 2017(26)	Controlled trials in which MMP-9 level was estimated from Gcf collected from canine at differe	18 healthy subjects, adolescents(11-14 years) and adults (21-45 years), with Class II Division 1 malocclusion requiring 4 first premol	Canines were retracted with a constant force of 50 cN. One canine was rando	18 healthy subjects	Adolescents: 13.3 6 0.9 Adults: 31 6 5.5	Gingival crevicular fluid was collected before orthodontic treatment and at days 1, 7, 14, and 28 after the canine	When compared with day 0, MMP- 9 concentrations increased significantly (P\0.05) 1, 7, and 14 days after canine retraction in both adults (6.6-

	nt intervals which were retracted using Niti closed coil spring of force 50 Cn from adolescents and adults.	ar extractions. Inclusion criteria: Age range, 11-14 or 21-45 years Exclusion criteria: Long-term use (6 month before study enrollment) of antibiotics, phenytoin, cyclosporin, anti- inflammatory drugs, systemic corticosteroids, and calcium channel blockers.	mly selected from each subject.			retraction.	, 5.5-, and 4.8- fold, respectively) and adolescents (3.6-,2.9-, and 2.7-fold, respectively). The increase at all 3 time points were significantly higher in adults than in adolescents (P\0.05). At day 28,MMP-9 Concentrations decreased to day 0 levels in both age groups (p 0.05)	
Xu et al, 2020 (19)	Controlled trial In which MMP - 9 levels of saliva in extraction and non extraction group were compared at different time points of orthodontic tooth movement	In total, 11 patients who needed tooth extraction and 11 patients who didn't before being subjected to fixed orthodontic appliance therapy were assigned into two groups: The extraction group and the non-extraction group. The subjects were required to be in good general health and had no periodontal disease or a history of treatment mune diseases, pregnancy, lactation, or use of any medication that could interfere with orthodont ic tooth move ment (e.g. antibiotics, antihistamines, cortisone, and hormones) within a month preceding the beginning of the study were excluded.	Two groups, extraction and non extraction groups	22 patients	Non-extraction group: 21.0±3.3 Extraction group: 22.7±2.8	The saliva samples were collected from each patient at four indicated time points, including the first visit time (T1), time before fitting the orthodontic appliance (T2), one hour after (T3) and eight weeks after fitting the appliance (T4). Salivary MMPs concentration was determined using multiplexed bead immunoassay.	In the non-extraction group, the concentration of MMP-9 were significantly increased at T3. In the extraction group, the concentration of MMP-9 increased during the orthodontic tooth movement process, reaching a peak at T3	
Sagar J. Jivrajani,	A randomized controlled study in whic	Ten patients (3males and 7 females)	The individual canine retraction was	Ten patients (3 males and 7	(14–24 years).	GCF was collected at basel	After three months of canine retraction and until the	
Wasundhara A. Bhad (Patil)(2020)	h Split mouth study was done in patients who required first premolar extraction to estimate MMP - 9 level in gcf which was collected from canine of experimental side and control side at different points of canine retraction using coil spring using 150 gm force.	who required maxillary first premolar extraction for routine orthodontic treatment were recruited. Patients with systemic illness, those under systemic medications, patients with impacted canines or canines having dilacerated roots were excluded from the study	studied, and the side of the experimental canine was randomly selected. The laser regimen was followed on the 1st, 3rd, 5th, 7th, 14th and then 15th days consecutively. GCF was collected at baseline, 14th day, 3 months and at the end of canine retraction on experimental side	females)		ine, 14th day, 3 months and at the end of canine retraction on experimental side and MMP-9 was estimated quantitatively using a standard ELISA kit.	completion of treatment (T1-T2) the change in marker expres- sion on experimental side was 0.013 ng/ml while on control side it was 0.51 ng/ml. The difference was statistically insignif- icant. The mean change in MMP-9 throughout the canine retraction on experimental side was 11.09 ng/mL while on control side it was 10.13 ng/ml and the difference was statistically insignificant	
Sioustis et al 2021(20)	Clinical trial in which salivary MMP 9 level changes was assessed at different points on patients who received fixed orthodontic treatment .	The inclusion criteria: 111 patients who were about to receive fixed orthodontic treatment .patients in generally good health who were about to receive fixed- appliance treatment and had a healthy periodontal status. The exclusion criteria were diagnosis of periodontal disease or a history of treatment, immune disease, systemic disease, smoking, pregnancy, lactation, and use of any medica	Orthodontic treatment was performed with a Roth prescription 0.022 bracket slot appliance .	111 patients aged between 18 and 39 years	25.5 _ 5.4 years	Saliva sampling. Unstimulated saliva was collected before placement of orthodontic appliances (T1), after the placement of orthodontic appliances but before periodontal therapy (T2), and during orthodontic treatment, one month after applyin	For salivary MMP-9 levels, the highest values were observed at T2, with a mean of 1.89 ± 1.82 ng/mL, and the lowest value was observed at T1, with a mean of 0.45±0.48 ng/mL . The mean MMP-9 level at T3 was significantly lower than that at T2 (p-value < 0.01),	

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		tion that could interfere with OTM (antihistamines, cortisone, and hormones)				g the periodontal treatment (T3).		
Lin et al, 2021[(21)]	Clinical trial in which MMP-9 level was estimated from Gcf was collected from both pressure and tension side of both study teeth (lower incisors) and control teeth (upper incisors)	This study recruited 18 healthy subjects (12–18 years old, 8 males, 10 females) undergoing OTM. The subjects had full permanent dentition and their Little Irregularity index was between 3 and 5 mm in the anterior segment of the lower arch,which allowed for continuous archwire for alignment and leveling. The exclusion criteria were autoimmune diseases, deep overbite, caries or restorations in the anterior teeth and the use of any drugs (such as antibiotics, antihistamines, cortisone and hormones) that might interfere with OTM in the first six months of the study	Orthodontic brackets (0.022×0.028-inch slot) were used. Then, an archwire (0.014-inch Nickel-Titanium) was inserted into the brackets of the lower teeth and bonded with modular elastics. For the upper arch, only modular elastics were placed. The lower incisors were the selected study teeth and the upper incisors were selected as control teeth.	18 healthy subjects undergoing OTM	(12–18 years old, 8 males, 10 females)	Gingival crevicular fluid (GCF) sampling. The collection time points were as follows: the day of application (T0), one hour (T1), 24 hours (T2), one week (T3), 4 weeks (T4) and 12 weeks (T5) after the application of orthodontic force.	The levels of MMP-9 of both tension and pressure side of the study teeth at T2- T4 were significantly up-regulated compared with that of T0 and T1 and decreased to baseline level at T5.for the control teeth cytokines at pressure and tension side were not significantly different at different times .	None

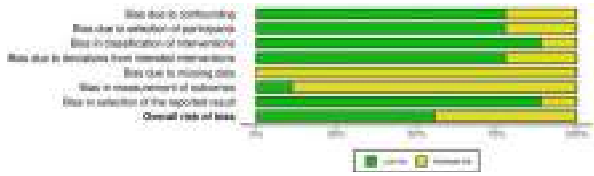

Figure 2: Risk of Bias of the included studies

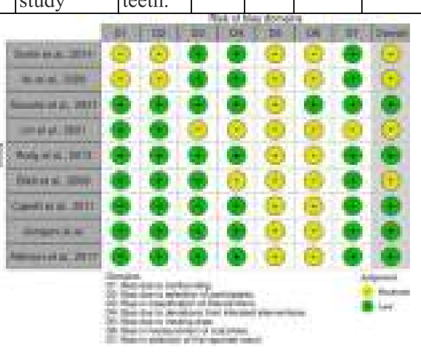

Figure 3: Overall summarative risk of bias of the studies included in the present systematic review

REFERENCES:

1. Wise GE, King GJ. Mechanisms of tooth eruption and orthodontic tooth movement. J Dent Res. 2008 May;87(5):414–34.
2. Meikle MC. Mechanobiology of tooth movement. Eur J Orthod. 2008 Jun;30(3): 299–306.
3. Li Y, Zhan Q, Bao M, Yi J, Li Y. Biomechanical and biological responses of periodontium in orthodontic tooth movement: update in a new decade. Int J Oral Sci. 2021 Jun 28;13:20.
4. Feller L, Khammissa RA, Schechter I, Moodley A, Thomadakis G, Lemmer J. Periodontal biological events associated with orthodontic tooth movement: the biomechanics of the cytoskeleton and the extracellular matrix. Sci World J. 2015;2015:894123.
5. Krishnan V, Davidovitch Z. On a path to unfolding the biological mechanisms of orthodontic tooth movement. J Dent Res. 2009 Jul;88(7):597– 608.
6. Apajalahti S, Sorsa T, Railavo S, Ingman T. The in vivo levels of matrix metalloproteinase-1 and -8 in gingival crevicular fluid during initial orthodontic tooth movement. J Dent Res. 2003 Aug;82(12):1018–22.
7. Kerosuo H. Adverse effects of orthodontic treatment: a clinical perspective. J Orofac Orthop. 2013;74(5):390–6.
8. Fischer T, Senn N, Riedl R. Design and structural evolution of matrix metalloproteinase inhibitors. Chem Eur J. 2019 Jun 18;25(34):7960–80.
9. Chung L, Dinakarpandian D, Yoshida N, Lauer-Fields JL, Fields GB, Visse R, et al. Collagenase unwinds triple-helical collagen prior to peptide bond hydrolysis. EMBO J. 2004 Aug 4;23(15):3020–30.
10. Nagase H, Woessner JF. Structure and function of matrix metalloproteinases and TIMPs. Cardiovasc Res. 2006 Aug 1;69(3):562–73.
11. Laronha H, Caldeira J. Structure and function of human matrix metalloproteinases. Cells. 2020 Apr 26;9(5):1076.
12. Ingman T, Sorsa T, Suomalainen K, Halinen S, Lindy O, Lauhio A, et al. Tetracycline inhibition and the cellular source of collagenase in gingival crevicular fluid in different periodontal diseases: a review. J Periodontol. 1993 Feb;64(2):82–8.
13. Birkedal-Hansen H. Role of matrix metalloproteinases in human periodontal diseases. J Periodontol. 1993 May;64(5 Suppl):474–84.
14. Ye S. Putative targeting of matrix metalloproteinase-8 in atherosclerosis. Pharmacol Ther. 2015 Mar;147:111–22.
15. Garlet TP, Coelho U, Silva JS, Garlet GP. Cytokine expression pattern in compression and tension sides of the periodontal ligament during orthodontic tooth movement in humans. Eur J Oral Sci. 2007 Oct;115(5):355–62.
16. Peres KG, Cascaes AM, Nascimento GG, Victora CG. Effect of breastfeeding on malocclusions: a systematic review and meta-analysis. Acta Paediatr. 2015 Dec;104 (467):54–61.
17. Tunçer BB, Küçükeşmen C, Tunçer C, Newell DH. Involvement of TSP1 and MMP9/NGAL in angiogenesis during orthodontic periodontal remodeling. Eur J Orthod. 2014 Aug;36(4):479–85.
18. Offenbacher S, Odle BM, Van Dyke TE. The use of crevicular fluid prostaglandin E2 levels as a predictor of periodontal attachment loss. J Periodontal Res. 1986 Mar;21(2):101–12.
19. Xu T, Zhang C. Levels of matrix metalloproteinases in saliva during orthodontic tooth movement. Orthod Craniofac Res. 2008 Aug;11(3):160–6.
20. Machoy M, Seeliger J, Koprowski R, Gedrange T, Woźniak K, Gedrange A, et al. Salivary metalloproteinase-8 and metalloproteinase-9 evaluation in patients undergoing fixed orthodontic treatment before and after periodontal therapy. J Clin Med. 2021 Feb;10(2):165.
21. Lin T, Yang L, Zheng W, Zhang B. Matrix metalloproteinases and Th17 cytokines in the gingival crevicular fluid during orthodontic tooth movement. Eur J Paediatr Dent. 2021 Jun;22(2):135–8.
22. Rody WJ, Wijegunasinghe M, Wiltshire WA, Dufault B. Differences in the gingival crevicular fluid composition between adults and adolescents undergoing orthodontic treatment. Angle Orthod. 2014 Jan;84(1):120–6.
23. Ingman T, Sorsa T, Halinen S, Haapasalo M, Konttinen YT, Lindy O, et al. Matrix metalloproteinases and tissue inhibitors of metalloproteinases in gingival crevicular fluid during orthodontic tooth movement. Eur J Orthod. 2009 Oct;31(5):529–35.
24. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, et al. Matrix metalloproteinases and chemokines in the gingival crevicular fluid during orthodontic tooth movement. Am J Orthod Dentofacial Orthop. 2011 Apr;139(4):e353–60.
25. Jaya SJ, Prasad WAB. Effect of low intensity laser therapy on MMP-9 expression in gingival crevicular fluid and rate of orthodontic tooth movement in patients undergoing canine retraction: a randomized controlled trial. Int Orthod. 2020 Jun;18(2):251–9.
26. Alikhani M, Chou MY, Khoo E, Alansari S, Kwal R, Elfersi T, et al. Age-dependent biologic response to orthodontic forces. Am J Orthod Dentofacial Orthop. 2018 May; 153(5):632–44.