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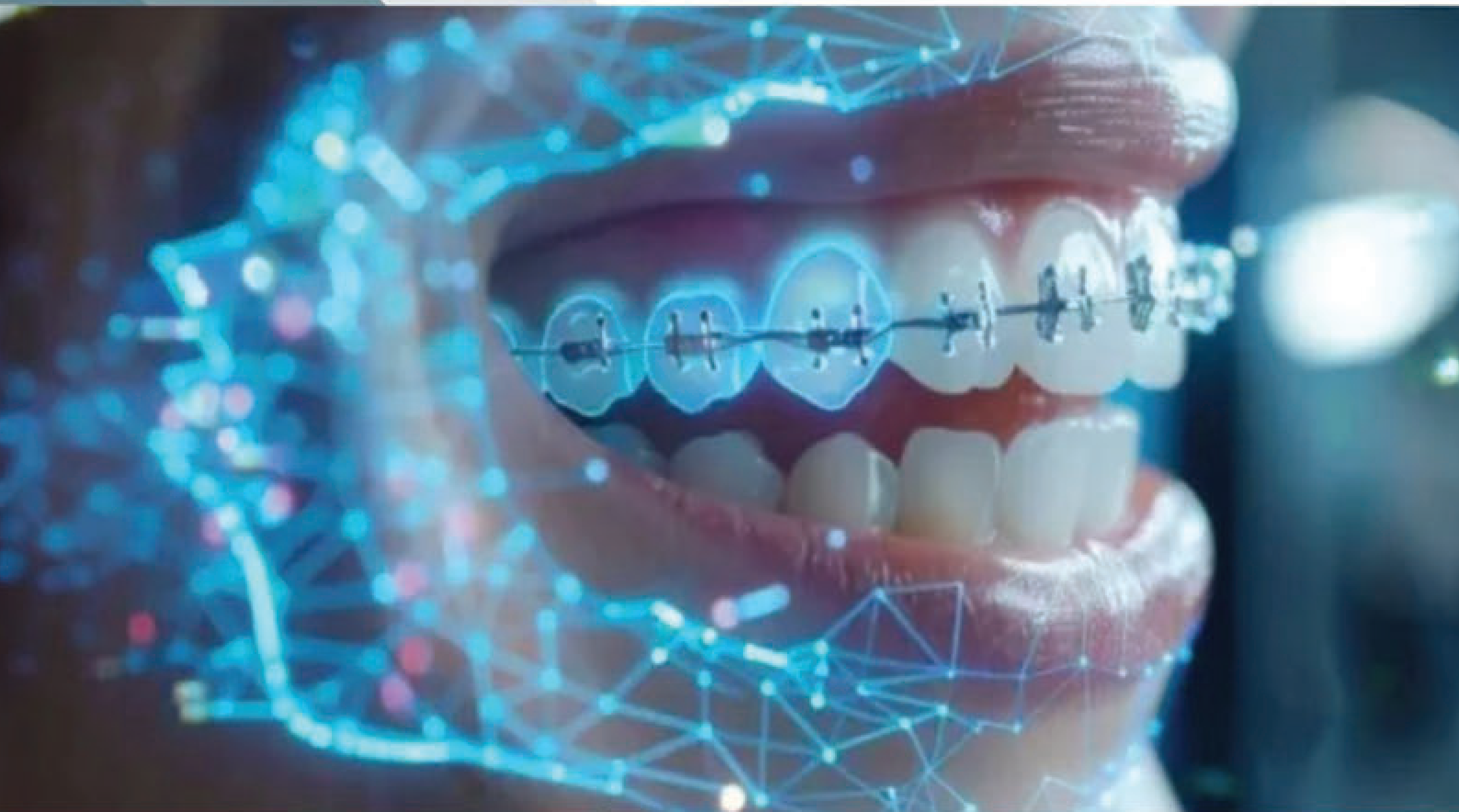

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Sri Lankan Journal of Orthodontics

Welcome to another edition of the Sr Lankan Journal of Orthodontics. We are all observing and participating in exciting changes in our discipline with the development and integration of technology into clinical practice. No matter where we deliver care, patients are more knowledgeable and desirous of opportunities to explore the various treatment options, exist to participate in these new AI driven platforms that will assist the clinician in diagnosis. development of treatment goals, planning and construction of the various appliance systems and monitoring the progress and ultimately the outcome of the treatment.

For some clinicians this may be exciting and others may be fearful of the unknown and the need to participate in continuing professional development to appreciate the nuances of the new systems and ensure can responsibly apply this to the patient's needs.

The uptake of these new technologies has historically been rapid, with many clinicians recklessly applying new procedures without any scientific basis, only to experience disappointment in the outcomes. Moreover there must be a cautious ethical approach to the new processes, where clinical innovations are being applied without a sound evidence based approach.

We are in the unique position where we play the most important role in our direct contact with our patients, firstly as a healthcare practitioner and secondarily as a business entity. It is up to us to create individual plans that satisfy the patient's desires based on their value system. It is only the individual clinician who has the knowledge and skills to assist the patients in making the right decision, to satisfy their desires and realistically direct them down the appropriate path with ethically driven goals in mind. Ethics are there to protect our patients from our value system getting in the way of what is best for the patient. In my opinion this key role will never be adequately and responsibly delegated to another mechanism.

We must be responsible and courageous in adopting these new approaches and we must personally be involved in adopting and managing these new systems within our individual comfort levels.

After all we are only human and this is why we chose to be a healthcare practitioner. Isn't it?

Dr Mithran Goonewardene
BDSc(West.Australia)
MMedSc(Harvard) Cert.Orth(Harvard/Forsyth)
Head of Orthodontics and Graduate Program Director
University of Western Australia
Australia

Association Between Over Jet Correction and Lower Incisor Proclination, Bilateral Symmetry and Gender Variation in Twin Block Treatment of Class II Division 1 Malocclusion: A Retrospective Study

VSN Vithanaarachchi[1], TMA Rodrigo[2]

[1]Professor in Orthodontics, Division of Orthodontics, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka.

[2]Senior Registrar, Division of Orthodontics, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka.

ABSTRACT:

Objective: To evaluate bilateral symmetry of overjet correction, quantify lower incisor proclination, and assess gender differences following Twin Block therapy in age-matched Class II Division 1 adolescents.

Methods: Retrospective analysis of 40 patients, 21 males 13.45 ± 1.40 years and 19 females 13.15 ± 1.31 years, treated with conventional Twin Block appliance. Pre- and post-treatment overjet and lower incisor to mandibular plane angle were measured. Paired t-tests, independent t-tests, and Pearson correlations were used.

Results: Mean overjet reduction was identical bilaterally: 5.679 ± 1.51 mm right and left, difference = 0.0000 mm, $p = 1.000$, $r = 0.970$, $p < 0.001$. LIA increased by 2.35 ± 2.11°, $p < 0.001$. No correlation existed between overjet reduction and LIA change: $r = -0.014$, $p = 0.932$ right; $r = 0.036$, $p = 0.825$ left. Gender differences were non-significant for overjet reduction, $p = 0.188$ right, $p = 0.453$ left, and LIA change, $p = 0.966$.

Conclusion: Twin Block appliance produces statistically symmetric overjet correction. Lower incisor proclination ~2.35° occurs but is not correlated with correction magnitude. Gender does not influence outcomes in age-matched circumpubertal patients.

Key words: Twin Block; Class II malocclusion; overjet; lower incisor proclination; bilateral symmetry; gender; functional appliance

INTRODUCTION:

Class II malocclusion is one of the most prevalent orthodontic problems, affecting approximately 15–20% of adolescents worldwide and often characterized by mandibular retrusion, increased overjet, and convex facial profile. Functional appliances are widely used during the growth period to stimulate mandibular growth and improve sagittal jaw relationships. Among these, the Twin Block appliance, introduced by Clark in 1982, remains one of the most popular due to its patient acceptability, rapid overjet reduction, and relatively simple design. [1-3]

The Twin Block consists of separate upper and lower acrylic bite blocks with 70° inclined planes that posture the mandible forward upon closure. This posturing is intended to harness growth modification by stretching the retro-discal tissues, activating lateral pterygoid muscles, and promoting condylar growth. Short-term randomized controlled trials have confirmed its effectiveness, reporting mean overjet reductions of 5.8–6.4 mm over 9–12 months of full-time wear. [3-5]

However, the skeletal vs dentoalveolar contribution to overjet correction remains debated. Systematic reviews estimate that about 60% of overjet reduction is dentoalveolar, primarily through lower incisor proclination and upper incisor retroclination, while 40% is skeletal due to increased mandibular length and SNB angle. This dentoalveolar component is a major concern clinically, as excessive lower incisor proclination can compromise periodontal health, stability, and limit future camouflage options. [6-9]

Proclination of mandibular incisors is a consistent side effect of functional appliance therapy and recent RCTs report 3.45° to 3.81° of lower incisor protrusion with conventional Twin Block appliance. Modified designs using mini-implant anchorage reduce this to 0.73–0.90°. Despite these data, clinicians often assume that larger overjet corrections will produce proportionally greater incisor tipping. Yet few studies have directly tested the correlation between sagittal correction magnitude and lower incisor inclination change. If no correlation exists, then LIA must be monitored independently of overjet severity during treatment planning. [10-13]

A fundamental assumption of Twin Block therapy is that bilateral bite blocks produce symmetric mandibular advancement. Asymmetric advancement could lead to midline deviations, occlusal canting, or temporomandibular joint issues. While clinical case reports occasionally note asymmetry due to appliance distortion or unilateral chewing, quantitative studies testing side-to-side differences in overjet reduction are scarce. Demonstrating statistical symmetry would validate the biomechanical design and reduce the need for bilateral monitoring in practice.[5][14]

Treatment timing is critical for functional appliances. The pubertal growth peak, corresponding to cervical vertebral maturation stages CS3–CS4, provides the greatest skeletal response. Systematic reviews show 3.3 mm additional mandibular growth when treatment includes this period. However, the influence of gender within this window is unclear. Most RCTs pool male and female subjects without stratifying outcomes. Since males and females differ in growth velocity and timing, it remains unknown whether Twin Block efficacy or side effects differ by gender when patients are age-matched in the 11–16-year range. [3,15-17]

Beyond dentoskeletal effects, mandibular advancement with Twin Block has been linked to increased pharyngeal airway dimensions. CBCT studies from 2024 report increases of 2.1 mm in superior pharyngeal airway space, 1.8 mm in middle airway, and 1.5 mm in inferior airway following Twin Block therapy. This may benefit Class II patients with airway constriction.

Symmetric mandibular positioning is likely a prerequisite for balanced airway expansion, further emphasizing the need to test bilateral symmetry of skeletal correction.[18][19]

Despite extensive research on Twin Block, three gaps persist: 1) Lack of quantitative data confirming bilateral symmetry of overjet correction; 2) No consensus on whether overjet reduction magnitude predicts lower incisor proclination; 3) Limited evidence on gender-specific responses in age-matched circumpubertal samples. Addressing these gaps would refine clinical protocols and aimed to conduct the following study.

STUDY AIMS:

Therefore, this retrospective study aimed to:

1. Quantify the bilateral symmetry of overjet reduction following Twin Block therapy;
2. Measure the mean change in lower incisor inclination and test its correlation with overjet reduction magnitude;
3. Compare treatment outcomes between age-matched male and female patients aged 11–16 years.

METHODS:

Study Design and Sample:

This retrospective cohort study was conducted using pre- and post-treatment records of patients treated with Twin Block appliances at Orthodontic clinic, Dental Teaching Hospital, Peradeniya between 2020 and 2024. Ethical approval was obtained from the Ethics and Review Committee of Faculty of Dental Sciences, University of Peradeniya.

Inclusion criteria were: 1) Class II Division 1 malocclusion with ANB > 4° and overjet ≥ 6 mm; 2) age 11–16 years at treatment start; 3) full permanent dentition excluding third molars; 4) treatment with standard Twin Block appliance only; 5) complete pre- and post-treatment dental casts and lateral cephalograms available. Exclusion criteria were: 1) previous orthodontic treatment; 2) craniofacial anomalies; 3) poor-quality records; 4) non-compliance documented in clinical notes.[3][20]

A total of 40 patients met criteria: 21 males, mean age 13.45 ± 1.40 years; 19 females, mean age 13.15 ± 1.31 years. Mean overall age was 13.30 ± 1.35 years. Groups were age-matched, p = 0.492.[3][17]

Appliance Design and Treatment Protocol:

All patients were treated with a standard Clark Twin Block design consisting of upper and lower acrylic bite blocks with 70° inclined planes. Construction bite was taken with 5–7 mm sagittal advancement and 2–4 mm vertical opening. Patients were instructed to wear the appliance full-time except during meals and contact sports. Average treatment duration was 11.2 ± 2.1 months.[1][7][12]

Data Collection:

Dental casts and lateral cephalograms were obtained at T0 pre-treatment and T1 post-functional phase, before fixed appliances. The following measurements were recorded:

1. Overjet: Measured on dental casts from the labial surface of the most proclined mandibular incisor to the labial surface of the most proclined maxillary incisor, parallel to the occlusal plane. Right and left sides measured separately to assess symmetry.
2. Lower incisor inclination (LIA): Measured on lateral cephalograms as the angle between the long axis of the mandibular central incisor and the mandibular plane (Go-Me) and Horizontal distance between N-B line and facial surface of the lower incisor. A single investigator performed all measurements after calibration.[11][14] Intra-examiner reliability was assessed by re-measuring 10 randomly selected cases 2 weeks apart. Intraclass correlation coefficient was 0.97 for overjet and 0.95 for LIA, indicating excellent reliability.[15]

STATISTICAL ANALYSIS:

Data were analyzed using SPSS v28.0. Normality was assessed with Shapiro-Wilk test. Paired t-tests compared T0–T1 changes and right vs left overjet. Independent t-tests compared males vs females. Pearson correlation tested relationships between overjet reduction and LIA change. Significance was set at $p < 0.05$. Sample size of 40 provided 80% power to detect a 1.0 mm overjet difference and 2.0° LIA difference at $\alpha = 0.05$.[3][20]

RESULTS:

Sample Characteristics:

The sample comprised 40 patients, 21 males and 19 females. No significant age difference existed between genders: males 13.45 ± 1.40 years, females 13.15 ± 1.31 years, p = 0.492. All patients were in the circumpubertal growth period.

Overjet Changes and Bilateral Symmetry:

Twin Block therapy produced statistically significant overjet reduction on both sides, $p < 0.001$. Mean pre-treatment overjet was 8.92 ± 1.82 mm right side and 8.95 ± 1.79 mm left side. Post-treatment overjet was 3.24 ± 0.91 mm right side and 3.27 ± 0.88 mm left side.

Mean overjet reduction was identical for right and left sides: 5.679 ± 1.51 mm. The difference between sides was 0.0000 mm, p = 1.000. A strong positive correlation existed between right and left overjet reduction, r = 0.970, $p < 0.001$, confirming symmetric correction.

Method	n	Side	Mean	Stdv.	95% CI for mean difference	p-value
Pre OJ	40	Right Side	9.125	1.825	(-0.0474, 0.2724)	0.163
	40	Left Side	9.012	1.933		
Post OJ	40	Right Side	3.462	1.232	(-0.0205, 0.1955)	0.109
	40	Left Side	3.375	1.249		
Differenc in OJ	39	Right Side	5.679	1.624	(-0.1533, 0.1533)	0.999
	39	Left Side	5.679	1.841		

Table 01: Pre and post over jet difference with twin block appliance

When stratified by gender, males showed clinically greater reductions, 6.00 ± 1.62 mm right and 5.90 ± 1.58 mm left, compared to females, 5.33 ± 1.39 mm right and 5.45 ± 1.42 mm left. However, these differences were not statistically significant: $p = 0.188$ right side, $p = 0.453$ left side.

Fig 02: Comparison of over jet difference (pre and post) in right and left side with twin block appliance

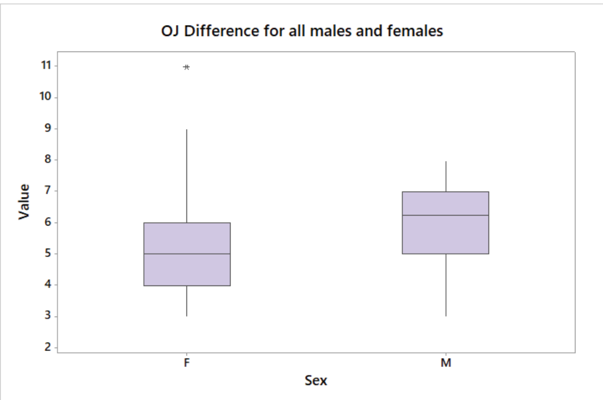

Fig 03: Comparison of over jet difference (pre and post) among males and females

Lower Incisor Inclination Changes:

LIA increased significantly from T0 to T1. Mean pre-treatment LIA was 94.12 ± 5.83° and post-treatment LIA was 96.47 ± 6.21°, mean change = 2.35 ± 2.11°, $p < 0.001$.

No significant gender difference was found for LIA change: males 2.38 ± 2.05°, females 2.33 ± 2.19°, $p = 0.966$.

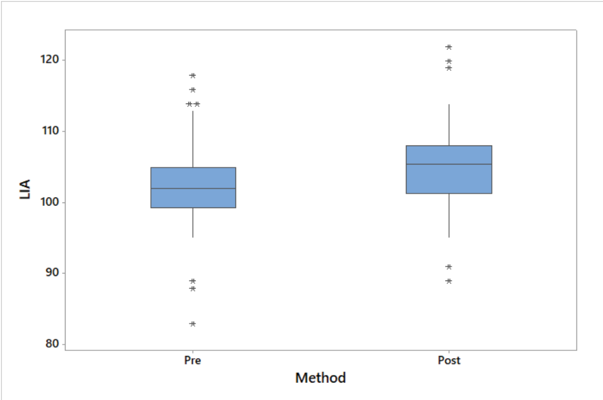

Fig 01: Comparison of pre and post lower incisor proclination with twin block appliance

Correlation Between Overjet Reduction and LIA Change:

Pearson correlation revealed no significant relationship between the amount of overjet reduction and LIA change for either side. Right side: $r = -0.014$, $p = 0.932$. Left side: $r = 0.036$, $p = 0.825$. This indicates that patients with greater overjet correction did not exhibit proportionally greater lower incisor proclination.

Correlation	Pearson Correlation Coefficient (ρ)	p-value	Decision
OJ Difference of Right side vs. Left Side	0.970	<0.001	Strong positive correlation
OJ Difference of Right Side vs. LIA Difference	-0.014	0.930	No Correlation
OJ Difference of Left Side vs. LIA Difference	0.036	0.828	No Correlation

Table 02: Correlation, coefficient of over jet reduction in right and left side with twin block appliance

DISCUSSION:

This retrospective study evaluated the effects of Twin Block appliance therapy on overjet correction and lower incisor inclination in Class II Division 1 patients, with emphasis on bilateral symmetry and gender variation.

Overjet Correction and Symmetry:

Twin Block therapy produced significant overjet reduction with perfect bilateral symmetry. Pre- and post-treatment overjet values were not significantly different between right and left sides, and mean reduction was identical at 5.679 mm for both sides, mean difference = 0.0000 mm, $p = 1.000$. The strong positive correlation, $r = 0.970$, $p < 0.001$, confirms symmetric correction. This supports the fundamental mechanism of the Twin Block, which advances the mandible bilaterally through inclined bite blocks. While most studies report overall overjet reduction, few specifically test bilateral symmetry. The finding of $p = 1.000$ for side-to-side difference provides rare quantitative evidence that Twin Block produces balanced sagittal correction, eliminating clinical concerns about asymmetric effects when the appliance is properly constructed.[3][4][5][14]

Lower Incisor Inclination and Its Relationship to Overjet Reduction:

Lower incisor proclination was a consistent finding, with a statistically significant mean increase of 2.35°. This magnitude aligns with prior reports of Twin Block side effects. A 2024 RCT found conventional Twin Block produced 3.81° of lower incisor protrusion, while modified designs with anchorage reduced it to 0.73°. Similarly, a comparative study reported 3.45° of lower incisor proclination with conventional Twin Block. This study shows 2.35° and which falls within this expected range and is considered clinically acceptable.[1][10][11][13][12]

The critical finding is the absence of correlation between overjet reduction and LIA change, $r = -0.014$ and $r = 0.036$, $p > 0.8$. This contradicts the assumption that greater sagittal correction necessitates greater incisor tipping. Sidlauskas et al. estimated 60% of overjet correction with Twin Block is dentoalveolar, but did not correlate it to LIA specifically. This study data show clinicians cannot predict incisor tipping from initial overjet severity. This supports recent work with clear aligner MA showing that dentoalveolar correction predominates over skeletal change, and that LIA must be monitored independently. Lombardo et al. 2024 also noted proclination of lower incisors with Twin Block as a consistent finding, but did not link it to overjet magnitude.[6][7][8][9]

Influence of Gender and Age:

The sample was well-matched for age: males 13.45 ± 1.40 years and females 13.15 ± 1.31 years, corresponding to the circumpubertal growth period optimal for functional therapy. Despite males showing clinically greater mean overjet reductions, 6.00 mm vs 5.33 mm right side and 5.90 mm vs 5.45 mm left side, these differences were not statistically significant, $p = 0.188$ and $p = 0.453$. Similarly, LIA change was nearly identical: 2.38° males vs 2.33° females, $p = 0.966$.

Recent literature rarely stratifies Twin Block outcomes by gender. Most RCTs pool males and females without reporting gender effects. This study observed non-significant findings suggest that within the 11–16 year age range, gender does not modify treatment response when groups are age-matched. This contrasts with studies emphasizing treatment timing over gender. A 2024 study confirmed that including the pubertal phase leads to more favorable mandibular growth, but did not find gender differences. The current research data support that individual skeletal maturation stage likely outweighs gender as a predictor.[3][15][16][17]

Timing and Skeletal Effects:

The study sample mean age of 13.30 years places most patients at CVM stages CS3–CS4, the pubertal growth peak. Treatment during this window maximizes mandibular response. The 3.3 mm increase in mandibular length reported with Twin Block and 4.60 mm increase in mandibular base length in other studies reflects this growth potential. While this study did not measure Co-Gn, the symmetric overjet reduction and age-matched sample suggest skeletal adaptation occurred. A 2024 systematic review confirmed Twin Block increases SNB and reduces ANB, consistent with mandibular advancement.[3][5][7][15]

Airway and Functional Considerations:

Though this study not measured here, recent studies show Twin Block increases pharyngeal airway dimensions: SPAS +2.1 mm, MAS +1.8 mm, PAS +1.5 mm. This is linked to mandibular advancement and may benefit Class II patients with reduced airway space. The symmetric overjet correction of this study observed suggests balanced mandibular positioning that could contribute to airway improvement, though CBCT would be needed to confirm.[18][19]

CLINICAL IMPLICATIONS:

1. Twin Block appliance produces symmetric overjet correction and bilateral monitoring is unnecessary if the appliance is symmetric.
2. Expect ~2–4° of lower incisor proclination, but do not assume it correlates with overjet severity. Monitor LIA independently.
3. Treatment is equally effective in males and females aged 11–16 years when age-matched. No protocol modification by gender is needed.
4. Modified Twin Block with mini-implant anchorage can reduce LIA proclination to <1° if control is critical.[1][5][6][8][9][11][12][13][15][16][17][10]

CONCLUSION:

Twin Block appliance therapy produces statistically significant and bilaterally symmetric overjet reduction in Class II Division 1 patients, $p = 1.000$ for side-to-side difference. Lower incisor proclination of 2.35° occurs following Twin Block therapy but is not significantly correlated with the amount of overjet correction, $r = -0.014$ and $r = 0.036$, $p > 0.8$. Gender does not significantly influence overjet reduction, $p = 0.188$ right side, $p = 0.453$ left side, or lower incisor proclination, $p = 0.966$, in age-matched adolescents. Twin Block therapy is equally effective for males and females during the circumpubertal period. Lower incisor inclination should be monitored independently of overjet correction magnitude.

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Congenitally Missing Lateral Incisors: preferences between orthodontists and general dentists- a mixed methods approach

Katherine Lambert Higgins[1], Meenakshi Vishwanath[2], Mohamed ElSalhy[3]

[1]Private Practice, Pediatric Dentistry & Orthodontics, Omaha, NE, USA

[2]Departmment of Orthodontics and Dentofacial Orthopedics, University of Missouri-Kansas City School of Dentistry, Kansas City, Missouri, USA

[3]Department of Preventative, Pediatric, & Community Dentistry, University of New England College of Dental Medicine, Portland, ME, USA

ABSTRACT:

Introduction: This study aimed to compare the preferences of general dentists and orthodontists in the esthetic management of Congenitally Missing Lateral Incisors (CMLI) and the rationale behind their preferences using a qualitative approach.

Methods: An online survey was distributed to general dentists and orthodontists. The survey included three clinical cases of CMLI followed by both qualitative and quantitative treatment planning questions.

Results: The sample size totaled 81 general dentists and 42 orthodontists. 86.6% of general dentists would refer CMLI cases to an orthodontist. In the canine substitution case, general dentists frequently selected no further treatment ($P<0.001$) or mechanical canine reshaping ($P=0.007$) compared to orthodontists. General dentists reported the need for more education on treating CMLI. The qualitative results yielded four themes when managing CMLI: conservative dentistry, optimal long-term outcome, esthetics, and airway concerns.

Conclusion: There is a general agreement between general dentists and orthodontists that implants are the preferred option for prosthetic replacement of CMLI, but they differ in their management of canine substitution. Conservative treatment, long-term success, and esthetics were driving forces behind the management approach for CMLI.

Clinical significance: The difference of canine substitution treatment preferences can be explained by dentists' varying treatment philosophies, which balance conservative dentistry and esthetics. This present study is the first to integrate qualitative data when analyzing CMLI treatment preferences.

Key Words: lateral incisor agenesis; CMLI; multidisciplinary treatment; canine substitution; maxillary lateral incisors

INTRODUCTION

Lateral incisors are the second most common tooth to be congenitally missing teeth after third molars.1 Several genes have been identified that are associated with congenitally missing teeth.2,3 Congenitally Missing Lateral Incisors (CMLI) affects 0.8%-2% of the population4,5 with an increase in its prevalence over the last decade.6 Maxillary lateral incisors are in the aesthetic zone so managing CMLI cases must address both the esthetic and the functional needs of the patient. Interdisciplinary treatment is necessary to produce the most predictable outcome when treating CMLI cases.[7] Given the complexity of the treatment plans, a team consisting of an orthodontist, general dentist, prosthodontist, periodontist, and oral surgeon can be necessary to manage these cases.

Patients who have congenitally missing lateral incisors typically have two main treatment options: restorative replacement of the lateral incisors or canine substitution.8 A patient's suitability for a given management option vs. the other depends on multiple factors. A patient's facial profile, facial type, tooth size, and occlusal relationship, including overjet, overbite, and molar relationship, are important factors to be considered.[9] CMLI has been linked to class III malocclusion.[10]

Dentists from different backgrounds may have different approaches to managing CMLI. General dentists, prosthodontists, and restorative dentists prefer prosthetic replacement of the lateral incisors, while orthodontists prefer to substitute the canine using orthodontic treatment.[11] With canine substitution, both the canine and premolar are relocated from their normal place in the arch.[3] This alters the proportions in the dental arch and may yield a less than ideal esthetic outcome. Surveyed dentists (including specialists) viewed prosthetic replacement as the most esthetic treatment option.[6] However, long-term esthetics of implants in the anterior region can be compromised overtime.[12] Natural teeth will super-erupt whereas implants will not, leading to a vertical height discrepancy of the teeth overtime.[12] Perceptions of ideal esthetics differ across providers.[12] It is also differs across patients. Patients should be informed about the expectations of different treatment options and the cases should be approached based on their uniqueness.

Determining adjunct treatments can also play an important role in the esthetic outcomes. The gingival contour and papilla have been identified as one of the most important factors when perceiving someone's smile.1 Patients treated with dental implants to manage CMLI have a more proportional smile.13 However, not all patients are candidates for implant placement. An in-depth evaluation of dentists' preferences on managing CMLI can help understand how they approach these cases. The purpose of this study was to examine dentists' preferred approaches to manage CMLI using specific clinical cases and the rationale behind their preferences.

METHODS

Participants in this mixed method cross-sectional study were dentists and dental residents. All 50 state dental associations were approached to distribute the survey to their members using their newsletter or sending it directly to their members. The survey was also sent to orthodontic, general practice (GPR), and advanced education in general dentistry (AEGD) residency program directors for distribution. The email consisted of a brief introduction and the link to the questionnaire. Prior to the survey distribution an orthodontic, prosthodontic, periodontal, and general dentistry faculty evaluated the survey for content validity. They evaluated the appropriateness of the cases and the provided options. After content validity, the survey was pre-tested with a group of dental students to detect ambiguity of words, misinterpretation of the options and any other problems with the questionnaire. The questions were adjusted based on participants comments. The study protocol was reviewed by the University's Institutional Review Board (Protocol# 02***-*4).

The survey was created and administered using RedCap. The survey consisted of two sections: demographics and treatment-planning. The demographic section consisted of 12 questions related to age, gender, specialty, location, and area of practice experience. The treatment-planning section consisted of three hypothetical cases of a 25-year-old female with class 1 occlusion. Each case had a short description of a patient, a clinical photo, and questions related to the case. Participants were asked to select their treatment options based on the exact case presented. Case 1 was presented only to general dentists and showed an untreated CMLI case with obvious spacing in the maxillary arch (Figure 1). The questions following Case 1 asked if the dentist would treat this case themselves, or refer to an orthodontist or prosthodontist. An option to select "other" was also provided. Participants were asked how they would prefer the specialist treat this case. Depending on which specialist they selected to refer to (if any), different options were provided. Orthodontic treatment options were to create space for prosthetic replacement of maxillary lateral incisors, close the lateral incisor space to substitute the canine, or let the orthodontist decide after evaluation. Prosthodontic treatment options were implants replacing maxillary lateral incisors, restore canines to look like lateral incisors, removable appliance, fixed partial dentures (FPD), resin bound bridge, or other. Participants were allowed to select more than one option.

Case 2 presented a patient who had orthodontic treatment to create space for prosthetic replacement of lateral incisors (Figure 2). All participants were presented with Case 2. Questions following Case 2 asked participants to rank their preferred treatment options from 1 through 6 (1 being the most preferable option) given the following options for prosthetic replacement of maxillary lateral incisors: implant retained crowns, cantilever bridges, FPDs, resin bound bridge, veneer bridge, or other. When "other" was selected, the participant had the opportunity to elaborate in their own words. A text box was provided to explain their rationale behind their treatment selections.

Case 3 presented a patient who had canine substitution completed by an orthodontist (Figure 3). Participants were asked to rank the treatment options from 1 through 6 given the options: reshape the canine with no restoration, reshape the canine using composite, veneer(s), crown(s), do nothing further, or other. A text box was provided to explain their rationale behind their treatment selection. Participants were asked if they would recommend any adjunct treatments to enhance the esthetic outcome of this case. The options provided were crown lengthening, whitening, gingivectomy, further orthodontic treatment (intruding the first premolar and extruding the canine), fixed lingual retainer, nothing further, and other. These recommendations were taken from previous literature [14,15].

STATISTICAL ANALYSIS

Quantitative data was managed and analyzed using SPSS 25.0 software (IBM Corp., Armonk, NY, USA). For data description, means and standard deviations were used for continuous items, and counts and percentages were used for categorical items. Differences between the proportion of general dentists and orthodontists responding to specific options were evaluated using t-test. All p-values less than 0.05 were considered statistically significant.

Participants' written responses were analyzed qualitatively using thematic analysis. The thematic analysis identified similar codes that were grouped into thematic categories. Related categories were then combined into key themes. Data was coded and categorized by two independent reviewers. Researchers discussed differences in coding, categories, and themes and reached a consensus.

RESULTS

Quantitative Results

Demographics	N	%
Age		
<30	26	21.0
30-45	47	37.9
46-60	18	14.5
>60	33	26.6
Gender		
Male	76	61.3
Female	48	38.7
Years practicing dentistry (mean (SD))	18.7 (SD=16.453)	-
Type of your current primary practice		
General Dentistry	81	65.3
Orthodontics	43	34.7
Practice location*		
Rural	32	25.8
Urban	72	58.1
Suburban	70	56.5
Other	2	1.6
Primary Patient Population		
Children (18 years old or younger)	39	31.5
Adults (19 years old or older)	85	68.5

* Participants were allowed to choose more than one option - total percentages adds to more than 100%

Table 1: Demographics

A total of 124 participants completed the survey. About 65.3% were general dentists and 34.7% were orthodontists. Orthodontic and general dentistry residents comprised 37.1% (n=46) of the total sample, while practitioners comprised 62.9% (n=78). About 61.3% of participants were male, and 79% reported age of more than 30-years-old. The mean years of experience for participants was 18.7 years. Most participants practice in urban and suburban areas, with only 25.8% practicing in rural communities. The demographic characteristics of participants are summarized in Table 1.

Management	N	%
Initial case management approach		
No referral - I would treat it myself	10	12.2
Referral for orthodontic evaluation	71	86.6
Referral for prosthodontic evaluation	1	1.2
No referral - treatment approach*		
Prosthetic replacements (Implants, FPD, RPD etc.)	6	4.8
Orthodontics	6	4.8
Restorative	1	0.8
Other	1	0.8
Referral - Preference for orthodontic treatment*		
Create space for prosthetic replacement of maxillary Lateral incisors	50	61.7
Close the lateral incisor space with the canine	8	9.9
Have the orthodontist decide after their evaluation	21	25.9
Referral - Preference for prosthodontic treatment*		
Place implants in place of #7 & #10	1	0.8
Restore the canines to look like lateral incisors	0	0
Removeable appliance	0	0
Fixed partial denture	0	0
Resin bound bridge/adhesive bridge	1	0.8
Other	0	0
*Participants were allowed to choose more than one option – total percentages adds to more than 100%		

Table 2: General dentists' approach to managing Case 1

Only 12.2% of general dentists who completed Case 1 reported treating the case themselves, whereas 87.8% would involve specialists such as orthodontists or prosthodontists. The participants who selected to refer this patient to an orthodontist preferred opening the lateral incisor space for prosthetic replacement of the maxillary lateral incisors (61.7%) compared to closing the space with canine substitution (9.9%). One-fourth of general dentists (25.9%) would leave the management decision to the orthodontist. General dentist's approaches to managing Case 1 are shown in Table 2.

Type of Practice	General dentist N	%	Orthodontists N	%	P-value
First choice preferences for prosthetic replacement of maxillary lateral incisors					
Implant retained crowns for #7 & #10	69	88.5	36	85.7	0.667
Cantilever bridge off #6 & #11	2	2.6	0	0.0	0.159
FPD(s) spanning from #6-#8 and #9-#11	0	0.0	0	0.0	-
Resin bound bridge	6	7.7	6	14.3	0.373
Venner bridge with Pontics #7 & #10	0	0.0	0	0.0	-
Other	2	2.6	0	0.0	0.160
First choice preferences for further treatment of canine substitution					
Reshape the canines with no restoration	4	5.1	10	23.3	0.018
Reshape the canines using resin composite	41	52.6	20	46.5	0.398
Veneer the anterior teeth	10	12.8	9	20.9	0.369
Crown the teeth	1	1.3	1	2.3	0.413
Do nothing futher	19	24.4	1	2.3	<0.001
Other	3	3.8	2	4.7	0.416
Adjunct treatments to enhance esthetic outcome of this case*					
Crown lengthening	19	23.5	10	23.3	0.980
Whitening tratments	40	49.4	21	48.8	0.954
Gingivectomy	24	29.6	14	32.6	0.739
Further orthodontic treatment - intrusion of the first PM and extrusion of the canine	7	8.6	15	34.9	0.002
Fixed lingual retainer	12	14.8	8	18.6	0.600
Other	3	3.7	3	7.0	0.423
No additional treatments	26	32.1	9	20.9	0.174

* Participants were allowed to choose more than one option – total percentages adds to more than 100%

Table 3: Participant's preferences for prosthetic replacement of maxillary lateral incisors, further treatment of canine substitution and adjunct treatments to enhance esthetic outcomes.

Implant retained crowns for maxillary lateral incisors were the first-choice treatment option for prosthetic replacement of CMLI (Case 2) by both general dentists (88.5%) and orthodontists (85.7%) (Table 3). The second most selected first choice treatment was a resin-bound bridge (14.3% orthodontists vs. 7.7% general dentists). Neither orthodontists nor general dentists chose a veneer bridge with pontics or fixed partial dentures as their first choice. Participants reported concerns with removing healthy tooth structure as the reason for not selecting veneer bridge with pontics or fixed partial dentures. Two general dentists selected "Other" as their first management choice. They listed cantilevers off the maxillary central incisors and a form of a temporary replacement.

Regarding treatment preferences in canine substitution when treating CMLI (Case 3), Orthodontists (46.5%) and general dentists (52.6%) ranked reshaping the canines using resin composite as their first-choice treatment option (Table 3). More orthodontists preferred to reshape the canines with no restoration than general dentists (23.3% vs. 5.1%, P = 0.018). More general dentists preferred to do nothing further compared to orthodontists (24.4% vs. 2.3%, P <0.001). Only two participants chose to crown the teeth as their first-choice treatment. Preserving healthy tooth structure was the main reason most participants did not prefer veneers or crowns.

About 88.1% of orthodontists recommended at least one adjunct treatment after canine substitution compared to 64.3% of general dentists. The most frequently selected adjunct treatment was teeth whitening by both orthodontists and general dentists (48.8% and 49.4%, respectively) (Table 3). Participants noted the color discrepancy in canines compared to other maxillary anterior teeth as the justification. More orthodontists recommended further orthodontic treatment to intrude the first premolar and extrude the canine compared to general dentists (34.9% vs. 8.6%, P = 0.002). Crown lengthening, gingivectomy, and fixed lingual retainers were also recommended by participants. About 32.1% of general dentists and 20.9% of orthodontists did not recommend any additional treatments to enhance the esthetic outcome of this case. Participants' preferences for prosthetic replacement of maxillary lateral incisors, further treatment of canine substitution, and adjunct treatments to enhance esthetic outcomes are shown in Table 3.

About 74.1% of general dentists and 90.7% of orthodontists believe that the cases presented require interdisciplinary management (P = 0.89). General dentists mentioned prosthodontists, orthodontists, and periodontists would be included in their multidisciplinary team while managing this case. About 48.1% of general dentists and 25.6% of orthodontists were interested in more continuing education training to manage CMLI cases (P = 0.023).

Qualitative Results

Four major themes emerged from the participants' written responses: necessity for further diagnostics, interdisciplinary management, conservative and long-term treatment, and airway concerns.

Participants felt they need more diagnostic information to reach an optimal management plan. Shared diagnostics included photographs, diagnostic models, diagnostic wax-up, radiographs (cephalometric/ CBCT), and caries risk. One general dentist stated:

"Would need models, I.O [Intra Oral] photos, and at least a good panorex to measure spaces, perform an aesthetic workup, and aesthetic wax-up in order to discuss our treatment plan for this patient." (General dentist, 89)

Participants highlighted the need for an interdisciplinary approach for treatment planning the case in an early stage. An orthodontist, a prosthodontist and a periodontist were suggested to be involved. The orthodontist is needed to plan the over-arching management of the case.

"The orthodontist will decide based on measurements unique to that patient. That's the decision factor." (General Dentist, 162)

"Prostho will be needed, however it needs coordinated with orthodontic treatment" (General Dentist, 150)

The need for the prosthodontist and the periodontist were proposed because the treatment is in the esthetic zone.

"Prosthodontist referral due to esthetic zone and possible need for multiple bone grafts, coordination with orthodontics for implants." (General Dentist, 130)

Both general dentist and orthodontists were in agreement that implant placement requires a specialist for the esthetic zone.

"I have seen poor implant placement more often than I would like, so I would prefer to start with a resin bound bridge, then go to an implant placed by a periodontist who is particular about esthetic results." (Orthodontist, 12)

Participants described the ideal treatment to be conservative, yet optimizes long-term success.

"My objective is to save as much tooth structure as possible and plan for the most long lasting and reliable result." (General Dentist, 62)

"Young patient with virgin abutment teeth - prioritize minimal tooth loss with resin bonded bridges or veneers over full coverage bridges." (General Dentist, 135)

They also highlighted the challenge between being conservative while optimizing esthetics.

"I would avoid crowns to preserve tooth structure. Shaping alone without restorations will likely require more compromised esthetics, so reshaping with composite or veneers would be my preferred approach. Which teeth to treat that would depend on the patient's concerns." (General Dentist, 29)

Although both general dentists and orthodontists are aiming to be conservative, orthodontists seemed to be more interested in optimizing esthetics compared to general dentists.

"The most conservative approach is my preferred method. I would place resin composite on #6 and #11." (Orthodontist, 49)

"Most esthetic with good long-term viability. I would refer for crown lengthening at substituted canines (first premolars) and then restore U3-3 with veneers. If the patient did not want to pursue that then I would only do composite at substituted laterals." (Orthodontist, 19)

There was a difference in how the "most conservative" approach was perceived between orthodontists and general dentists. Orthodontists' "most conservative" approach was to reshape the canines with resin, while when general dentists' "most conservative" approach was to do nothing further.

"Would try to be as noninvasive as possible. Preferably none [of the suggested restorative treatments]" (General Dentist, 68)

Some general dentists mentioned airway concerns while planning the case. They favored avoiding any approach that may reduce the maxillary width.

"I'd like to avoid making the patient's mouth smaller to avoid sleep apnea. Ideally I'd like to expand make room for lateral incisors." (General Dentist, 32)

"I would want to address hidden airway concerns and deficient maxillary width" (General Dentist, 163)

DISCUSSION

This study aimed was to examine dentists' preferred approaches to manage CMLI by comparing general dentists to orthodontists. General dentists prefer to refer CMLI cases to orthodontists for planning and management. Both general dentists and orthodontists prefer implant-retained crowns as a prosthetic replacement for the missing maxillary later incisor. In canine substitution cases, reshaping the canine using resin composite was preferred by both general dentists and orthodontists. More general dentists preferred no future esthetic treatment after canine substitution. Participants considered many factors when managing CMLI including conservative dentistry, planning for the optimal long-term outcome, esthetics, and airway concerns.

Majority of general dentists prefer to refer CMLI cases to an orthodontist for treatment, with a few involving a prosthodontist at early stages. Participants remarked that an orthodontic evaluation is valuable at the early planning stage because orthodontists can provide a space analysis. Upon acquiring the necessary measurements for space analysis, the best treatment option for this patient can be determined.

A number of general dentists declined to involve specialists and chose to treat the patient themselves. Those general dentists felt that they can provide the necessary orthodontics combined with any prosthodontic treatment, if needed. Some of those practice in rural areas. A general dentist may not have an orthodontist to refer to, so they must provide the entire treatment for patients with CMLI.

A consultation with an orthodontist would provide general dentists the information to determine the best plan of treatment for patients with CMLI. If given the option of opening the lateral spaces followed by prosthetic replacement vs. canine substitution, general dentists preferred the former option. This result agrees with a previous study which concluded that general dentists prefer CMLI be treated by prosthetic replacement as compared to canine substitution citing best esthetic outcomes.12 In contrast, orthodontists prefer canine substitution and believe ideal esthetics could be achieved.12 Participants in this present study listed concerns of narrowing the maxillary arch leading to sleep apnea and conserving tooth structure as reasons for selecting opening the lateral spaces followed by prosthetic replacement with implants. Sleep apnea has not been reported as a negative outcome in canine substitution of CMLI cases. Since extracting maxillary premolars has no impact on pharyngeal airway volume,16, 17 airway impact is not expected in canine substitution cases. Given the concern reported by general dentists, more education is necessary to eliminate such misconception.

When comparing the preferences for prosthetic replacement of maxillary lateral incisors, there was no significant difference between orthodontists and general dentists. Both general dentists and orthodontists prefer prosthetic replacement with implants. This agrees with a previous study who found that general dentists and orthodontists overwhelmingly preferred implant retained crowns over FPDs, cantilever crowns, and adhesive bridges.11 Implants are the most conservative option because they do not require modification of healthy tooth structure.7 This was the main reason cited by participants for selecting implant retained crowns as their first choice. While implant retained crowns were the most frequently selected by participants, precautions were noted when placing implants in the esthetic zone. Hard and soft tissue can undergo unpredictable changes around implant retained crowns.18-21 For this reason, it is contraindicated to place implants in the anterior maxilla in patients with a high smile line.11,21 Some participants recognized this risk and recommended periodontists place the implants in these cases. Periodontists will take esthetics into concern during implant placement.

The timing of implant placement is one of its downfalls, yet general dentists still prefer to treat CMLI with prosthetic replacement. Growth must be completed before implants can be placed which is 20 to 21 years old for males and 16 to 17 years or older for females 7 with several authors reporting craniofacial vertical growth continuing into adulthood.23 Having missing teeth in the anterior region is not ideal for any age, but especially through adolescence. Given that hypodontia has negative psychosocial consequences on young people24, perhaps canine substitution combined with esthetic dentistry is considered more frequently. However, the cases shared with participants in this study were adult cases. This may be one of the reasons that the majority of participants gave preferences to prosthetic replacement with implants compared to canine substitution.

There is limited literature on the preferred treatment options after canine substitution of CMLI cases, especially when comparing preferences of orthodontists and general dentists. Reshaping using resin composite was the most frequently selected treatment option in the present study. However, many participants also preferred no further treatment, reshaping the canine, or using veneers. Significantly more general dentists opted for no further treatment compared to orthodontists. A theme noted throughout the qualitative data was being conservative while optimizing long-term success. This theme echoes previous literature which emphasizes the importance of selecting a treatment with optimal long-term success.14 CMLI is treated at a young age and is expected to last a lifetime. Starting with the most conservative approach such as resin bonding, allows a more invasive, but more esthetic treatment such as veneers, to be an option in the future. Treating additional maxillary teeth for optimal esthetics was also recommended in previous literature.14 Some participants in our study recommended veneering the central incisors and/or first premolars in addition to the canines will provide an optimal esthetic result. Although being conservative is a priority, the patient esthetic demands should be always taken into consideration.

Space closure with canine substitution cases are growing in popularity.14 Outcomes are improved when combined with esthetic dentistry.14,15 In this study, orthodontists were more likely to recommend additional treatment to enhance the esthetics after canine substitution compared to general dentists. There was minimal explanation from participants behind their recommendation for specific adjunct treatments, if any; but the concern for esthetics was stronger amongst orthodontists than general dentists. Orthodontists more frequently recommended treating adjacent maxillary anterior teeth in canine substitution cases for optimal esthetics. Recommendations such as orthodontically intruding the first pre-molar and extruding the canine and veneering the canines and their adjacent teeth were some of the treatments suggested.

An interesting discrepancy between general dentists and orthodontists in their perception or definition of being “conservative” was noted during the qualitative analysis. Orthodontists noted their “conservative” approach would be to do resin restorations on the maxillary laterals, while general dentists explained their conservative approach was to do nothing further. While both orthodontists and general dentists were concerned about being conservative in removing tooth structure, orthodontists mentioned optimal esthetics more frequently in explaining their treatment selection.

Treatment of congenitally missing lateral incisors is complicated due to their location in the esthetic zone. The ideal approach should include an interdisciplinary team of orthodontists, prosthodontists, and periodontists. However, the treatment is commonly initiated by general dentists. General dentists are the leader of a patient’s treatment plan. They should have sufficient education on treating these cases to understand the possible options to provide the best individualized result for the patient. Our results showed general dentists feel they need further education on how to manage CMLI.

The results from our study only represent those who choose to participate in the study. Given that it is hard to track which program directors and state dental associations dispersed the survey to their residents and members as asked, estimating the response rate is not possible. Without a response rate, generalizability of the results is limited. In addition, a cross-sectional study design brings the perspectives and opinions related to information provided to them. In this study, we asked participants to expand upon their choices qualitatively to help us further understand their reasoning. To simplify the cases, we instructed participants to answer the questions as if the occlusal relationship was Class I molar occlusion. Participants' responses may have differed had they been presented a patient with a different occlusal relationship given that occlusion is an integral part in determining the treatment plan for patients with congenitally missing lateral incisors. Numerous participants noted their preferences would partially rely on occlusion. In addition, the age of the patient provided in these cases (25 years old) was a determining factor in how participants chose to treat the case. A growing adolescent does not have the same treatment options as a 25-year-old female due to ongoing growth and development. Treatment preferences may differ given the age of the patient, crowding concerns, and occlusion.

CONCLUSIONS

Within the limitations of this current study, it is concluded that general dentists prefer referring CMLI cases to orthodontists for planning and management. In cases of prosthetic replacement for the maxillary lateral incisors, both general dentists and orthodontists prefer implant-retained crowns. In canine substitution cases, reshaping the canine using resin composite was the preferred treatment by both general dentists and orthodontists. More general dentists preferred no additional esthetic treatment after canine substitution, while orthodontists more frequently opted for adjunct esthetic treatments. Interdisciplinary management is critical to the success of CMLI cases. The individual needs of each patient, and conservative yet esthetic treatment should all be taken into consideration when managing patients with CMLI. Furthermore, there is a need for enhanced education especially among general dentists regarding vertical craniofacial growth patterns, as this knowledge plays a key role in diagnosis, treatment timing, and appropriate referral decisions, ultimately contributing to more predictable and stable treatment outcomes.

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Figure 1

This photo was included in the first case presented to participants which depicts a patient untreated for congenitally missing lateral incisors. The caption included: "Case #1: A 25-year-old patient with a chief complaint of "I have spacing in my top front teeth" Please evaluate this case and answer the following questions. Assume this patient has class I molar occlusion.

Figure 2

This photo was presented to participants as the "second case" mimicking a patient who had orthodontic treatment to allow for restoration of maxillary lateral incisors. Participants were asked to rank their treatment preferences for restoring #7 & #10 in this case. The caption included was: "Case 2: Patient has completed orthodontic treatment and has bilateral space for restoring maxillary lateral incisors. Assume the patient has class I molar occlusion."

Figure 3

This photo was presented to participants as the "third case" providing an example of a patient who had canine substitution to treat CMLI. The caption included stated: "Case 3: Patient has completed orthodontic treatment to close the bilateral spaces due to missing maxillary lateral incisors using canine substitution. The patient was referred to you to manage esthetics, if needed"

Defining Safe Zones for Inter-radicular Temporary Anchorage Device Placement in the Anterior Maxillary Region of a Sri Lankan Population: A CBCT Study

Dr A Rajaganesh[1], Senadeera HDSS[2], Jayasinghe RD[3], Gunatissa CN[4], Weerasinghe JT[5]

[1]Faculty of Dental Sciences, University of Sri Jayewardenepura, Sri Lanka

[2]Colombo South Teaching Hospital Kalubowila

[3]Department of Oral Medicine and Periodontology, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

[4]National Dental Hospital Sri Lanka

[5]National Dental Hospital Sri Lanka

ABSTRACT

Objective: To identify safe anatomical sites in the anterior maxilla for inter-radicular Temporary Anchorage Device (TAD) placement in the Sri Lankan population using CBCT imaging to improve treatment safety and efficacy.

Methods and materials: Out of a total of 150 CBCT scans obtained from Faculty of Dental Sciences, University of Peradeniya, Sri Lanka, 48 scans fulfilled the eligibility criteria and were included in the analysis. Measurements were obtained from five anterior maxillary inter-radicular regions. Inter-radicular width, bucco-lingual alveolar bone thickness, and buccal cortical bone thickness were measured at 3 mm, 5 mm, 7 mm, and 9 mm apical to the alveolar crest.

Results: At 3 mm and 5 mm levels, inter-radicular dimensions were generally insufficient for safe TAD placement. At 7 mm, only the region between the maxillary central incisors exceeded the recommended safe threshold of 2.5mm. At 9 mm, all regions exceeded the recommended safe threshold, except the left central-lateral incisor (21–22) region. Bucco-lingual alveolar bone thickness ranged approximately from 7.16 mm to 8.4 mm across all sites. Buccal cortical bone thickness ranged from 0.84 mm to 1.20 mm, with the greatest values observed in the central incisor region.

Conclusion: The safest zones for anterior maxillary TAD placement in the Sri Lankan population were identified between the maxillary central incisors and between the lateral incisors and canines, particularly at more apical levels. Although bucco-lingual bone thickness and cortical bone thickness were generally favourable, inter-radicular width remained the principal limiting factor.

Keywords: CBCT, Orthodontic Mini-Implants, Anterior Maxilla, TAD, Interradicular Safe Zones

INTRODUCTION

Temporary anchorage devices (TADs),commonly referred to as mini-implants or mini screws, are now a versatile armamentarium in contemporary orthodontic practice. They are small bone screws placed in attached gingivae, engaging with cortical and cancellous bone temporarily to enhance orthodontic anchorage. They either support the teeth of the reactive unit or obviate the need for the reactive unit altogether and are subsequently removed after use(1–3). The introduction of TADs has significantly expanded the scope of orthodontic treatment by enabling more controlled tooth movement while minimising undesirable reciprocal effects.

In clinical orthodontics, mini-implants placed in the anterior maxillary region serve multiple purposes, including intrusion of over-erupted incisors, correction of midline discrepancies, space closure, management of anterior open bite cases, and optimisation of space distribution prior to prosthetic replacement (4) (5,6). Furthermore, the increasing popularity of clear aligner therapy and interdisciplinary treatment planning has increased the demand for reliable anchorage systems in aesthetically demanding regions. The anterior maxilla, considered from canine to canine, presents a unique and anatomically demanding environment for TAD placement. It is characterised by narrow inter radicular spaces, thin labial cortical plates and the nasopalatine canal in the midline (4). The posterior maxillary region is a more common location for TAD placement. Many papers have been published with regards to safe TAD zones in the posterior maxilla. However, evidence is scarce in the anterior maxillary region.

Successful TADs are those which remain stable under normal orthodontic force application (150-200g) for a minimum of 6 months. (1,7) Several factors influence the success and stability of TADs. These include skeletal characteristics, insertion site anatomy, cortical bone thickness, bone density, soft tissue conditions, implant design, insertion technique, and operator-related factors. Among these factors, root proximity has been identified as one of the most significant causes of mini-implant failure. Contact between the mini-implant and adjacent roots may compromise blood supply, interfere with bone remodelling, induce unfavourable biomechanical forces and ultimately result in implant failure. Consequently, previous authors have recommended maintaining a minimum clearance of 0.5mm between the mini-implant and adjacent roots to minimise complications and preserve periodontal health (8). However As TADs can migrate up to 1.5 mm, some authors recommend at least 1 mm of safety clearance (9).

Bone characteristics also play an important role in determining the primary and secondary stability of TADs. Primary stability refers to the mechanical interlocking achieved immediately after insertion and is considered to be the single most important factor in the survival of a TAD and depends on bone quantity, quality and thickness, as well as soft tissue thickness (10). Previous studies have suggested that cortical bone thickness between 1 mm and 2 mm appears favourable for adequate primary stability, while cancellous bone contributes to secondary stability through bone remodelling. Furthermore, cortical bone thickness and density vary considerably between different anatomical regions and among individuals. The anterior maxillary region generally demonstrates thinner buccal cortical bone compared with palatal regions, which may influence the success of TAD placement.

Cone beam computed tomography (CBCT) has emerged as an invaluable imaging modality for evaluating potential TAD insertion sites. CBCT provides high-resolution, three-dimensional visualisation of dental and skeletal structures without the superimposition and distortion commonly associated with conventional two-dimensional radiographs (11). Previous investigations have demonstrated that CBCT significantly improves the accuracy of implant positioning, reduces the likelihood of root contact, and enhances initial stability by allowing precise assessment of interdental space, cortical bone thickness, and surrounding anatomical structures (4,12–14). Despite these advantages, CBCT is not routinely prescribed solely for TAD assessment because of considerations related to radiation exposure, cost and availability. In many clinical settings, including Sri Lanka, orthopantomograms are more commonly used because they are affordable and widely accessible. However, conventional two-dimensional radiographs are subject to distortion, magnification errors, and reduced precision for linear measurements(15,16). Moreover, CBCT facilities are not yet widely available throughout Sri Lanka, particularly outside major urban centers.

Although several studies have evaluated posterior inter-radicular areas and generalised safe zones for mini-implant placement, there remains limited evidence specifically evaluating the anterior maxillary region. More importantly, no comprehensive CBCT-based data are currently available regarding safe inter-radicular TAD placement zones in the Sri Lankan population. Considering that craniofacial morphology and alveolar bone dimensions may vary among populations, the absence of population-specific reference values creates a knowledge gap. Acquisition of evidence based safe zones for inter-radicular TAD placement would assist orthodontists in selecting the most favourable insertion sites, determining appropriate vertical levels for placement, and minimising the risk of root damage. Furthermore, population specific anatomical reference values would enhance treatment planning, improve patient safety, and contribute to the growing body of regional orthodontic research.

Accordingly, this study aims to define safe zones for inter-radicular temporary anchorage device placement in the anterior maxillary region of the Sri Lankan population using cone beam computed tomography. By evaluating inter-radicular distance and relevant bone characteristics on CBCT images, this research seeks to generate clinically applicable guidelines for safer and more predictable TAD placement in routine orthodontic practice.

METHODS

This retrospective cross-sectional study was conducted using archived cone-beam computed tomography scans obtained from the Division of Oral Medicine and Radiology, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka, from January 2023 to December 2023. Ethical approval was obtained from the Ethics Review Committee of the University of Sri Jayewardenepura prior to commencement of the study. Only previously acquired CBCT scans taken for diagnostic purposes were utilised, and no additional radiation exposure was incurred for research purposes. All patient identifiers were removed prior to analysis to ensure confidentiality. Patient consent was obtained by the institution, including consent for the use of data for research.

A total of 150 CBCT scans of Sri Lankan patients aged between 12 and 40 years were selected according to predefined eligibility criteria. Scans demonstrating complete permanent dentition in the regions of interest, adequate image quality, and clear visualisation of the alveolar processes were included in the study. Exclusion criteria comprised scans with motion artefacts, metallic artefacts, severe crowding, mixed dentition, impacted teeth affecting the measurement area, previous orthodontic treatment involving the anterior maxilla, and pathological lesions such as cysts, tumours, or severe periodontal bone loss. Out of a total of 150 CBCT scans 48 qualified for data collection.

All scans had been acquired using a Vatech CBCT unit under institutionally standardised exposure protocols. DICOM datasets were imported into Horos DICOM Viewer software and analysed using the 3D Multiplanar Reconstruction mode. Measurements were performed for five anterior maxillary inter-radicular regions from right canine to left canine.

For measurements between the maxillary right and left central incisors, the Multi Planer Reconstruction (MPR) reference crosshairs were initially aligned in the sagittal view with the vertical reference line passing through the long axis of the upper right central incisor and the horizontal reference line adjusted to pass through the alveolar crest (Figure 1). In the corresponding axial view, the vertical reference line was positioned to bisect the inter-radicular area while the horizontal reference line passed through the midpoint between the roots of the adjacent teeth (Figure 2).

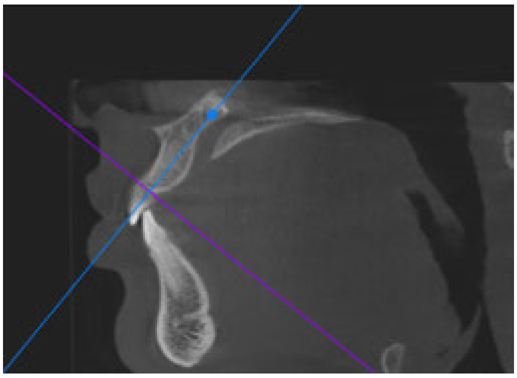


Figure 1 - Sagittal view

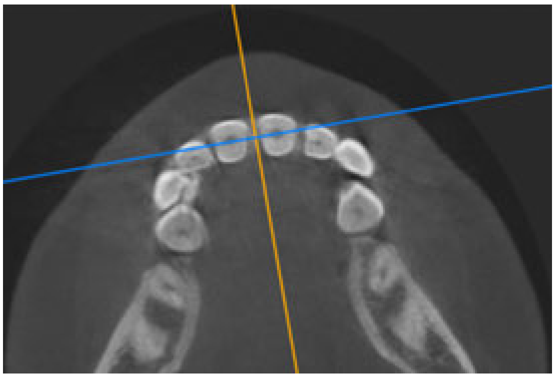


Figure 2 - Axial view

Using this orientation, inter-radicular width measurements were obtained in the coronal view at 3 mm, 5 mm, 7 mm, and 9 mm apical to the alveolar crest (Figure 3). In the same sagittal section, bucco-lingual alveolar bone thickness measurements were recorded at 3 mm, 5 mm, 7 mm, and 9 mm perpendicular to the long axis of the tooth (Figure 4). Buccal cortical bone thickness was also measured at the same levels in the sagittal view.

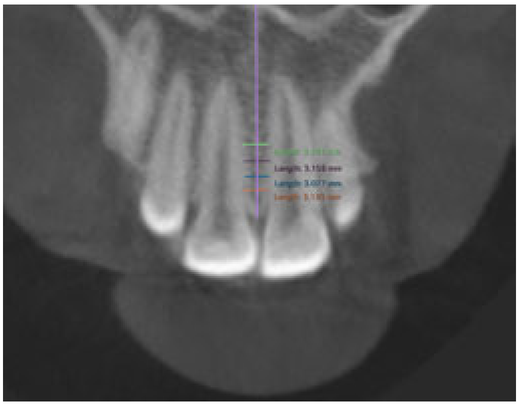


Figure 3 - Coronal view

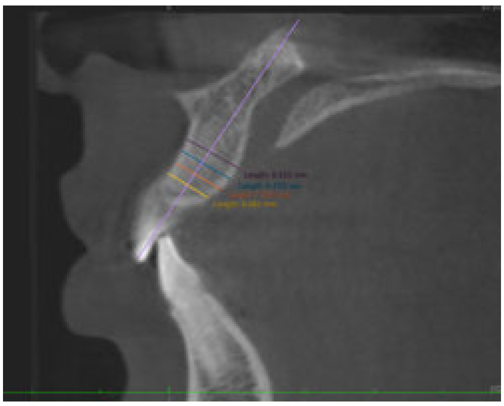


Figure 3 - Coronal view

The same procedure was repeated for the remaining inter-radicular regions. For each maxilla, a total of 60 measurements were obtained. All measurements were performed directly on the computer display monitor.

All measurements were performed independently by a single examiner. Twenty randomly selected scans were re-evaluated after a two-week interval to assess intra-examiner reliability using intraclass correlation coefficients and Dahlberg's error formula. Data were analyzed using SPSS software. Descriptive statistics including mean, standard deviation, minimum, maximum, and 95% confidence intervals were calculated for each site and level. Statistical significance was set at $p < 0.05$.

RESULTS

Normality of the data was assessed using the Shapiro–Wilk and Kolmogorov–Smirnov tests. Variables demonstrating normal distribution were summarised using mean and standard deviation, whereas non-normally distributed variables were described using median and range.

Inter-radicular width

The mean inter-radicular width in the anterior maxilla increased progressively with vertical distance from the cemento-enamel junction (CEJ) across all sites (Table 1). At 3 mm and 5 mm from the CEJ, inter-radicular distances were consistently less than 2.5 mm at all sites, indicating insufficient space for safe temporary anchorage device (TAD) placement.

At 7 mm, a modest increase in inter-radicular space was observed, however, only the midline region (11–21) approached the threshold (2.95 mm), while all other sites remained less than 2.5 mm.

At 9 mm, further increases were evident, with the midline region (11–21) demonstrating the greatest inter-radicular width (3.30 mm). Adjacent sites which were right canine-right lateral (13–12), right lateral-right central(12–11), and left lateral-left canine (22–23) also exceeded the clinically accepted safe threshold of 2.5 mm, while the left central-left lateral (21–22) region remained less than 2.5 mm even at this level.

Bucco-lingual alveolar bone thickness

Bucco-lingual alveolar bone thickness ranged from approximately 7.16 mm to 8.40 mm across all evaluated sites and levels. The greatest thickness was consistently observed between the maxillary right central and lateral incisors and between the maxillary central incisors regions, while slightly lower values were observed in the lateral incisor–canine regions. Minimal variation in bucco-lingual thickness was observed across different vertical levels. (Table 2)

Buccal cortical bone thickness

Buccal cortical bone thickness ranged from 0.84 mm to 1.20 mm across all evaluated sites. The greatest cortical thickness was observed in the central incisor region, particularly at the 5–9 mm levels. Lateral regions demonstrated comparatively thinner cortical bone. (Table 3)

Based on the predefined threshold criteria, the clearly favourable safe zones for anterior maxillary TAD placement was identified at 7mm from CEJ between the maxillary central incisors, and at 9 mm at all sites except for left central-left lateral (21–22) region.

Table 1: Inter radicular width

Distance from the alveolar crest		13-12	12-11	11-21	21-22	22-23
3mm	Mean	2.2021	1.8894	2.4478	1.7833	2.0022
	Median	2.0000*	1.8000*	2.2500*	1.7000	2.0000*
	Std. Deviation	.69704	.47330	.79099	.46692	.60092
5mm	Mean	2.3936	2.3404	2.6522	1.8771	2.2152
	Median	2.2000*	1.9000*	2.4000*	1.7000	2.1000*
	Std. Deviation	.87362	.47330	.96695	.54975	.68959
7mm	Mean	2.6217	2.2391	3.1217	2.1396	2.5717
	Median	2.4000*	2.1000*	2.9500*	2.0000*	2.4000*
	Std. Deviation	1.01542	.67148	1.15430	.63906	.82156
9mm	Mean	2.9500	2.5783	3.5217	2.4087	2.8667
	Median	2.7500*	2.5000*	3.3000*	2.1500*	2.9000*
	Std. Deviation	1.15311	.89540	1.36885	.88990	.92072

* Non normal distribution

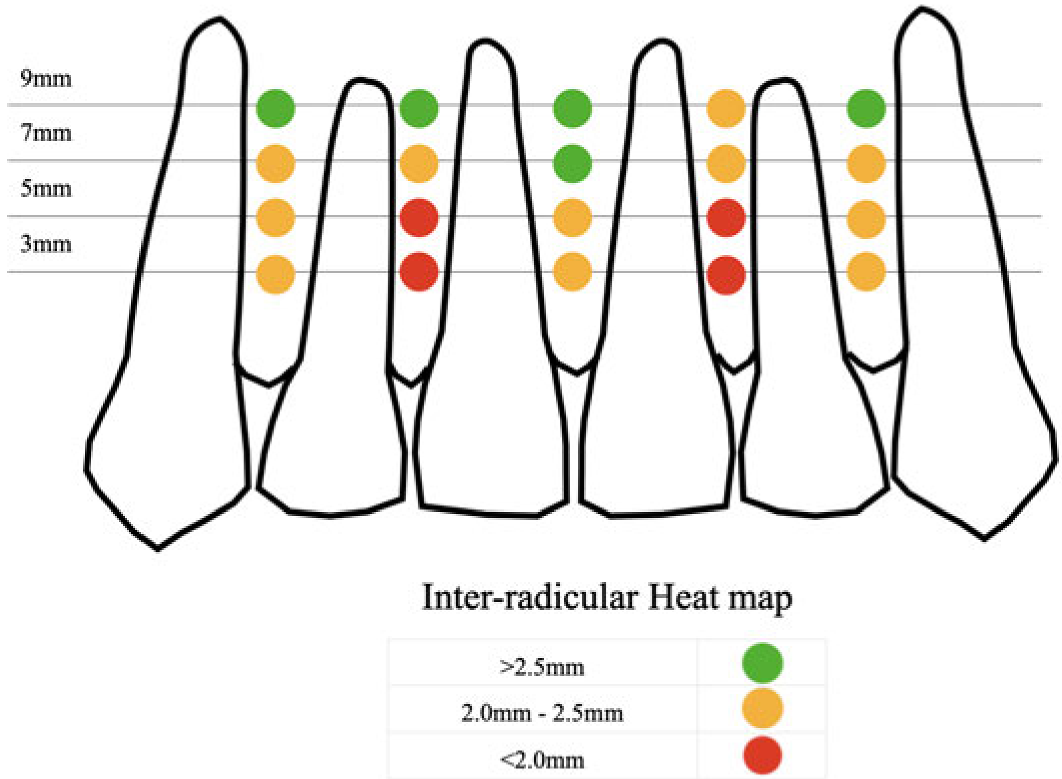
Table 2: Bucco-lingual alveolar bone thickness

Distance from the alveolar crest		13-12	12-11	11-21	21-22	22-23
3mm	Mean	7.2862	8.5064	8.3152	7.2826	7.3228
	Median	7.0000	8.4000*	8.3000	7.1600*	7.3000*
	Std. Deviation	1.35501	1.07974	1.10694	1.47944	1.11137
5mm	Mean	9.0546	8.6298	8.2630	7.8255	7.8913
	Median	7.2950*	8.4000*	8.1000*	7.3900*	7.5000*
	Std. Deviation	1.45716	1.32007	1.09977	2.02316	1.57065
7mm	Mean	7.6786	8.6391	7.9702	7.7516	7.9897
	Median	7.3450*	8.4000*	8.1000	7.5200*	7.5000*
	Std. Deviation	1.88145	1.25104	1.36380	1.92810	1.99066
9mm	Mean	7.6181	8.7956	8.3739	7.8039	7.8894
	Median	7.4900*	8.4000*	8.3000*	7.5900*	7.7900*
	Std. Deviation	1.98604	1.52195	1.19674	1.86204	2.05089
					* Non normal distribution	

Table 3: Buccal cortical bone thickness						
Distance from the alveolar crest		13-12	12-11	11-21	21-22	22-23
3mm	Mean	.9221	1.1277	1.1109	.9345	.9661
	Median	.8700*	1.2000	1.1000	.8450*	.9000
	Std. Deviation	.33757	.26102	.30712	.31874	.35359
5mm	Mean	.9508	1.2468	1.1130	.9853	.9850
	Median	.9100*	1.2000*	1.0500*	.8700*	.8650*
	Std. Deviation	.31210	.39112	.43236	.40734	.38263
7mm	Mean	1.0351	1.2609	1.1872	1.1082	1.1033
	Median	.8800*	1.1500*	1.1000*	.8750*	.9700*
	Std. Deviation	.42786	.41819	.42662	.60990	.48547
9mm	Mean	1.0521	1.2457	1.2170	1.0331	1.1382
	Median	.9000*	1.2000*	1.2000*	.9100*	1.0700*
	Std. Deviation	.46540	.33909	.42289	.42009	.50179

* Non normal distribution

Figure 5



DISCUSSION

This study evaluated inter-radicular width, bucco-lingual alveolar bone thickness, and buccal cortical bone thickness in the anterior maxillary region from canine to canine in a Sri Lankan population using CBCT imaging in order to identify safe zones for temporary anchorage device placement. The findings revealed that inter-radicular width increased progressively with increasing vertical distance from the alveolar crest, with the greatest dimensions observed at the 9 mm level. However, despite this gradual increase, only a limited number of sites fulfilled the criteria considered safe for TAD insertion. Among the evaluated regions, the area between the maxillary central incisors and between laterals and canines were identified as the most favourable sites for TAD placement.

The selection of a safe inter-radicular site is critical for minimising complications such as root damage, periodontal injury, TAD instability, and implant failure. Previous studies have emphasised that inadequate interdental space is one of the major causes of root contact and subsequent mini-implant failure (8,17,18). In the present study, a minimum inter-radicular width of 2.5 mm was considered acceptable for safe placement, allowing approximately 0.5 mm clearance from adjacent roots (8). This criterion differs slightly from recommendations by other authors who suggested a minimum interdental width of 3 mm to accommodate a mini-implant safely while maintaining adequate periodontal clearance (10). Nevertheless, both approaches emphasise the importance of maintaining sufficient separation between the TAD and adjacent roots.

The results of the present study demonstrated that inter-radicular width increased progressively away from the CEJ, which is consistent with several previous CBCT-based investigations (4,19,20). Similar to previous studies, the greatest inter-radicular width in the present sample was observed between the maxillary central incisors. The inter-radicular width between the two maxillary central incisors increased from 2.25 mm at the 3 mm level to 3.30 mm at the 9 mm level. This finding supports the concept that more apical levels provide safer insertion sites for TAD placement due to increased root divergence.

However, compared with previously published studies, the inter-radicular widths observed in the Sri Lankan population were relatively smaller. Previous investigators reported inter-radicular widths exceeding 4 mm in certain anterior maxillary regions (4), whereas the maximum value observed in the present study was 3.30 mm. These differences may reflect racial and anatomical variations in alveolar bone morphology and root anatomy. Therefore, population-specific data are essential when planning TAD placement, particularly in anatomically sensitive areas such as the anterior maxilla.

The relatively narrow inter-radicular dimensions observed in the Sri Lankan sample indicate that smaller diameter mini-implants may be preferable in this population. Previous studies have recommended mini-implants with diameters ranging from 1.3 mm to 1.5 mm and lengths of 5–7 mm for inter-radicular placement (5,10,18). The reduced interdental space observed in the present study further supports the use of narrow-diameter TADs to minimise the risk of root proximity while maintaining adequate mechanical stability.

The present study also demonstrated that bucco-lingual alveolar bone thickness was generally adequate across all evaluated regions, ranging from approximately 7 mm to 8.4 mm. These findings were comparable to previous CBCT studies (19). Adequate bucco-lingual bone thickness is important because it contributes to the overall bone volume available for TAD stabilisation and permits the use of shorter mini-implants without compromising stability.

Based on the present findings, the use of TADs with lengths of approximately 6–7 mm appears appropriate for the anterior maxillary region in the Sri Lankan population. This recommendation is consistent with previous reports indicating that mini-implant lengths of 6–8 mm provide adequate primary stability while minimising the risk of injury to adjacent anatomical structures (5,10,21). Since bucco-lingual dimensions were adequate in most regions, the major limiting factor for TAD placement in the present study appears to be inter-radicular width rather than bone depth

Buccal cortical bone thickness is another important factor influencing primary stability. In the present study, buccal cortical bone thickness ranged from 0.87 mm to 1.2 mm, with the greatest values observed in the central incisor region. Similar findings have been reported in previous CBCT investigations. Cortical bone thickness between 1 mm and 2 mm has been reported to provide favourable primary stability (1). Therefore, the cortical bone thickness values observed in the present study appear clinically acceptable for anterior maxillary TAD placement. More than 2mm leads to greater stress concentration on the cortical plate (1). While cortex might resorb, cancellous bone aids in secondary stability by remodelling at the compression side of orthodontic tooth movement. Moreover, high cortex density results in better stability (1).

The findings of the present study also emphasise the importance of insertion level in determining safe zones. Traditionally, the region approximately 5 mm above the alveolar crest has been considered favourable because it corresponds to attached gingiva (4,5). However, the safest inter-radicular dimensions in the present study were generally observed at 7 mm and 9 mm levels, which may extend beyond attached gingiva in some patients. TAD placement is planned near the mucogingival junction (5 mm from the alveolar crest and above), which may lead to the elevated risks of reduced stability, TAD loss, and chronic soft tissue inflammation (22,23). Solutions such as modified screw heads (24), variations in thread design (25), or adjustments to the insertion angle may

provide additional stability (26). This may necessitate modifications in insertion angulation, careful soft tissue management, or the use of TAD designs suitable for placement in alveolar mucosa.

Although CBCT is not routinely prescribed solely for TAD assessment in all clinical settings, it provides valuable three-dimensional information regarding root proximity, cortical thickness, and bone morphology that cannot be reliably assessed using conventional two-dimensional radiographs. In resource-limited settings such as Sri Lanka, routine CBCT imaging for every TAD case may not always be feasible. Nevertheless, the present study provides valuable population-specific reference values that may guide clinicians in selecting safer insertion sites in the anterior maxilla.

Despite its strengths, the study has several limitations. The analysis was limited to linear measurements, and factors such as bone density, insertion angle, soft tissue thickness, and actual clinical success rates were not evaluated. Furthermore, the study was limited to a Sri Lankan sample and therefore may not be directly generalisable to other populations. Future studies incorporating bone density assessment and clinical outcome evaluation would provide additional insight into optimising TAD placement in the anterior maxillary region.

CONCIUSION

Within the limitations of this CBCT-based study, the inter-radicular region between the maxillary central incisors and between laterals and canines demonstrated the most favourable dimensions for TAD placement in the anterior maxilla of the Sri Lankan population, particularly at more apical levels. Inter-radicular width increased progressively away from the CEJ, whereas bucco-lingual bone thickness and buccal cortical bone thickness remained generally adequate across all evaluated regions. These findings emphasise the importance of careful radiographic assessment and individualised treatment planning when placing TADs in the anterior maxillary region. The population-specific reference values generated in this study may assist clinicians in improving the safety and predictability of anterior maxillary TAD placement in routine orthodontic practice.

CONFLICTS OF INTEREST

None

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Not applicable

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Comparative Evaluation of MMP-13 and ICTP as Biomarkers of Orthodontic Tooth Movement in Patients Treated with Thermoformed and Direct 3D-Printed Clear Aligners: A Prospective Clinical Study

Dr. Shikhil mohan[1], Dr Jayanth K[2], Dr. Swarna Alamelu[3], Dr. N.R. Krishnaswamy[4]

[1,2]Former Post Graduate student,Department of Orthodontics and Dentofacial Orthopaedics,Ragas Dental College and Hospital,Chennai.

[3]Professor,Department of Periodontics,Ragas Dental College and Hospital,Chennai.

[4]Former Professor and Head,Department of Orthodontics and Dentofacial Orthopaedics,Ragas Dental College and Hospital,Chennai.

ABSTRACT:

Introduction- To compare the temporal expression of Matrix Metalloproteinase-13 (MMP-13) and Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type I Collagen (ICTP) in gingival crevicular fluid (GCF) and whole unstimulated saliva (UWS) of patients treated with thermoformed and direct three-dimensional (3D)-printed clear aligners and to evaluate their association with orthodontic tooth movement.

Methods- Eight healthy adults requiring non-extraction clear aligner therapy were randomly allocated to thermoformed aligners (Invisalign SmartTrack®; n = 4) or direct 3D-printed aligners (Graphy TA-28®; n = 4). GCF and UWS samples were collected at baseline and Weeks 1, 2, 3, 4, and 6. MMP-13 and ICTP concentrations were quantified using enzyme-linked immunosorbent assay. Clinical tooth movement was assessed from occlusal photographs obtained at baseline, Week 3, and Week 6.

Results- Both biomarkers exhibited temporal changes throughout the 6-week observation period, indicating active periodontal remodeling. GCF consistently demonstrated higher biomarker concentrations and more distinct temporal variations than saliva. Direct 3D-printed aligners showed greater MMP-13 and ICTP expression than thermoformed aligners. At Week 6, clinical tooth movement was greater in the direct 3D-printed aligner group (approximately 2.25 mm) than in the thermoformed aligner group (approximately 0.9 mm). Positive correlations were observed between biomarker expression and the magnitude of tooth movement.

Conclusions- MMP-13 and ICTP provide complementary information regarding extracellular matrix remodeling and alveolar bone resorption during orthodontic tooth movement. Direct 3D-printed aligners were associated with greater biomarker expression and increased tooth movement than thermoformed aligners, while GCF proved more sensitive than saliva for detecting localized periodontal remodeling. These findings support the potential of a dual-biomarker approach for monitoring biological responses during clear aligner therapy.

INTRODUCTION

Orthodontic tooth movement (OTM) is a highly regulated biological process initiated by the application of controlled mechanical forces to teeth, resulting in coordinated remodeling of the periodontal ligament (PDL) and alveolar bone. Mechanical loading generates areas of compression and tension within the PDL, triggering mechanotransduction pathways that stimulate the release of inflammatory cytokines, chemokines, growth factors, and matrix-remodeling enzymes. These molecular events regulate extracellular matrix degradation, osteoclast recruitment, osteoblast activation, and alveolar bone remodeling, ultimately facilitating controlled tooth movement while maintaining periodontal tissue homeostasis.[1-6] Although the biomechanical principles governing OTM are well established, the biological response to orthodontic force varies considerably among individuals, influencing treatment efficiency, duration, and the risk of adverse effects such as root resorption and periodontal tissue damage.[3-7]

In recent years, increasing attention has been directed toward identifying biological markers capable of objectively monitoring the tissue response to orthodontic forces. Biomarkers provide insight into the molecular events occurring within the periodontal tissues before clinical changes become evident and have the potential to facilitate biologically guided orthodontic treatment.[8-11] Among the various biological samples investigated, **gingival crevicular fluid (GCF) and whole unstimulated saliva (UWS)** have emerged as attractive diagnostic media because they can be collected repeatedly using minimally invasive techniques. GCF reflects the local periodontal environment and contains numerous inflammatory mediators and tissue-remodeling molecules released during orthodontic tooth movement, whereas saliva represents a convenient oral fluid that may serve as a non-invasive medium for biomarker assessment.[12-16]

Extracellular matrix remodeling is one of the earliest biological events following orthodontic force application. Matrix metalloproteinases (MMPs) constitute a family of zinc-dependent endopeptidases that degrade extracellular matrix components and facilitate cellular migration and tissue remodeling.[16-20] Among them, Matrix Metalloproteinase-13 (MMP-13), also known as collagenase-3, exhibits high affinity for fibrillar collagens, particularly type I, II, and III collagen, which are the principal structural components of the periodontal ligament and alveolar bone matrix. Mechanical stimulation of periodontal ligament fibroblasts, osteoblasts, osteocytes, and inflammatory cells induces MMP-13 expression, promoting collagen degradation and extracellular **matrix turnover. Increased MMP-13** activity facilitates osteoclast recruitment and bone remodeling, making it a potential early biomarker of orthodontic tissue remodeling.[21-25]

While MMP-13 reflects active enzymatic degradation of the extracellular matrix, **Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type I Collagen (ICTP)** represents a biochemical degradation product released during osteoclastic breakdown of mature type I collagen. ICTP is generated following collagen degradation during alveolar bone resorption and therefore serves as a sensitive indicator of bone turnover rather than enzymatic activity itself. Elevated ICTP concentrations have been reported during active orthodontic tooth movement, reflecting increased osteoclastic activity and periodontal remodeling. Consequently, MMP-13 and ICTP represent biologically distinct yet complementary markers of the remodeling process: MMP-13 reflects extracellular matrix remodeling, whereas ICTP reflects collagen degradation associated with bone resorption.[26-31]

Most previous investigations have evaluated individual biomarkers in isolation, limiting the understanding of the sequential biological events that characterize orthodontic tooth movement. Simultaneous assessment of MMP-13 and ICTP from the same biological samples provides an opportunity to evaluate complementary phases of periodontal remodeling within a single clinical model. Such a **dual-biomarker approach** may provide a more comprehensive understanding of tissue responses than studies relying on a single molecular marker and may improve the ability to monitor the biological efficiency of orthodontic treatment.[32]

Parallel to advances in biomarker research, clear aligner therapy has undergone rapid technological evolution. Conventional thermoformed aligners are fabricated by vacuum- or pressure-forming thermoplastic sheets over three-dimensional printed dental models. Although clinically effective, the thermoforming process may alter material thickness, elasticity, force delivery, and dimensional accuracy [33-36]. Recent advances in additive manufacturing have enabled the fabrication of **direct three-dimensional (3D)-printed clear aligners**, eliminating the thermoforming step and offering improved adaptation, more uniform thickness, enhanced geometric precision, and potentially more consistent orthodontic force delivery. Preliminary investigations suggest that direct 3D-printed aligners may improve treatment efficiency ; however, evidence regarding their biological effects on periodontal tissue remodeling remains limited.[33-39]

Understanding the biological response elicited by different aligner systems is essential for the development of evidence-based and personalized orthodontic treatment protocols. Evaluation of complementary biomarkers such as MMP-13 and ICTP may provide objective evidence of extracellular matrix remodeling and alveolar bone turnover while simultaneously correlating these molecular changes with clinical tooth movement. Such an approach has the potential to advance biomarker-guided orthodontics by enabling clinicians to monitor treatment response at the molecular level and optimize treatment strategies according to individual biological variability.

Therefore, the present prospective clinical study was undertaken to compare the temporal expression of MMP-13 and ICTP in gingival crevicular fluid and whole unstimulated saliva collected from the same participants undergoing orthodontic treatment with thermoformed and direct 3D-printed clear aligners. The study also aimed to evaluate the complementary expression patterns of these biomarkers and to correlate their levels with the amount of orthodontic tooth movement achieved during treatment. It was hypothesized that direct 3D-printed aligners would produce greater biological activity, reflected by increased expression of both MMP-13 and ICTP, resulting in enhanced orthodontic tooth movement compared with conventional thermoformed aligners.

MATERIALS AND METHODS

Study Design

This prospective, randomized clinical study was conducted to evaluate the temporal expression of Matrix Metalloproteinase-13 (MMP-13) and Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type I Collagen (ICTP) during orthodontic tooth movement in patients treated with thermoformed and direct three-dimensional (3D)-printed clear aligners. Both biomarkers were quantified from aliquots of the same gingival crevicular fluid (GCF) and whole unstimulated saliva (UWS) samples collected from each participant at predetermined time intervals. Clinical tooth movement was simultaneously assessed to determine the relationship between biomarker expression and orthodontic treatment efficiency.

Study Setting

The study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics, Ragas dental college and hospital, Tamil Nadu, India.

Participant Recruitment

Participants seeking orthodontic treatment with clear aligners were screened for eligibility. Eight healthy adult patients requiring non-extraction orthodontic treatment with clear aligners were recruited. Participants were randomly allocated into two treatment groups:

- Group I (Control): Thermoformed clear aligners (Invisalign SmartTrack®)
- Group II (Experimental): Direct 3D-printed clear aligners (Graphy TA-28®)

Each group consisted of four participants.

Eligibility Criteria

Inclusion Criteria

Participants who fulfilled all of the following criteria were included:

- Age between 18 and 40 years
- Permanent dentition
- Mild to moderate anterior crowding requiring non-extraction treatment
- Good periodontal health
- Good oral hygiene
- No previous orthodontic treatment
- Willingness to participate and provide written informed consent

Exclusion Criteria

Participants were excluded if they had:

- Active periodontal disease
- Systemic diseases affecting bone metabolism
- Pregnancy or lactation
- Current smoking habit
- Use of anti-inflammatory drugs, corticosteroids, bisphosphonates, or medications affecting bone remodeling
- Craniofacial anomalies
- Previous orthodontic treatment

Sample Size

A total of eight participants were included in the study to evaluate bone remodelling temporally with multiple sampling. This is the first of its kind where samples were collected at every week interval with the change of the aligner. This was considered a pilot study which could pave way for a future randomized clinical trial. So, no sample size calculation was done in this study.

Randomization

Eligible participants were randomly assigned to either the thermoformed aligner group or the direct 3D-printed aligner group using a computer-generated random allocation sequence.

Allocation concealment was maintained until commencement of treatment.

Orthodontic Treatment Protocol

All participants underwent comprehensive orthodontic records including intraoral scanning.

Treatment planning was performed using digital orthodontic software.

Group I received thermoformed aligners fabricated using Invisalign SmartTrack material.

Group II received direct 3D-printed aligners fabricated using Graphy TA-28 printable resin.33-38

Participants were instructed to wear the aligners for approximately 22 hours per day except during meals and oral hygiene procedures.

No auxiliaries or adjunctive acceleration procedures were employed during the observation period.

Collection of Gingival Crevicular Fluid (GCF)

GCF samples were collected from the designated tooth using graduated microcapillary pipettes after isolation of the operative field and gentle air drying.

Supragingival plaque was removed before sample collection.

Samples were collected at:

- Baseline
- Week 1
- Week 2
- Week 3
- Week 4
- Week 6

The collected GCF volume of 2 μl was eluted into a sterile microcentrifuge tube (Eppendorf) containing PBS and was immediately transferred into and stored at −80°C until biochemical analysis.10,12,14

Collection of Whole Unstimulated Saliva (UWS)

Whole unstimulated saliva samples were collected under standardized conditions.

Participants were instructed to avoid eating, drinking, tooth brushing, and chewing gum for at least one hour before sample collection.

Approximately 2–5 mL of unstimulated saliva was collected into sterile polypropylene tubes.

Samples were centrifuged to remove cellular debris and stored at −80°C until analysis.

Quantification of MMP-13 and ICTP

Frozen GCF and saliva samples were thawed immediately before analysis.

Aliquots from the same biological specimens were analyzed independently for:

- Matrix Metalloproteinase-13 (MMP-13)
- Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type 1 Collagen (ICTP)

Commercially available sandwich enzyme-linked immunosorbent assay (ELISA) kits were used according to the manufacturer's instructions.

Optical density was measured using a microplate reader, and biomarker concentrations were calculated from standard calibration curves.

All assays were performed under identical laboratory conditions to minimize analytical variability.

Measurement of Orthodontic Tooth Movement

Clinical tooth movement was evaluated using standardized occlusal photographs obtained at:

- Baseline
- Week 3
- Week 6

Images were calibrated using a known reference dimension to eliminate magnification error.

The amount of space closure was measured digitally using image-analysis software.

Measurements were performed by a calibrated examiner blinded to treatment allocation.

Outcome Measures

Primary Outcome

- Temporal expression of MMP-13 and ICTP in GCF and saliva.

Secondary Outcomes

- Comparison of biomarker expression between thermoformed and direct 3D-printed aligners.
- Comparison of biomarker concentrations between GCF and saliva.
- Clinical tooth movement.
- Correlation between biomarker expression and tooth movement.
- Evaluation of the complementary expression patterns of MMP-13 and ICTP during orthodontic tooth movement.

Statistical Analysis

Data were analyzed using **IBM SPSS Statistics** (version 26.0).

Descriptive statistics were calculated for all variables.

Changes in biomarker concentrations over time were evaluated using appropriate parametric statistical tests, including Student's t-tests and analysis of variance (ANOVA), with Pearson's correlation coefficient used to assess relationships between biomarker levels and clinical tooth movement.

A two-sided p value of < 0.05 was considered statistically significant.

RESULTS

Participant Characteristics

Eight healthy adult participants (four males and four females) requiring non-extraction orthodontic treatment with clear aligners completed the study. Participants were randomly allocated into two treatment groups: Group I (thermoformed aligners) and Group II (direct 3D-printed aligners), with four participants in each group. No participant was lost to follow-up, and all scheduled biological samples and clinical measurements were successfully collected and analyzed.

Table 1 : SAMPLE GROUPING

GROUPS	APPLIANCE TYPE
I (n=4)	THERMOFORMED ALIGNER
II (n=4)	DIRECT PRINTED ALIGNER

Table 1a : SAMPLE GROUPING - sub groups

GROUPS	SUB GROUPS (BASED ON SAMPLE COLLECTION WEEKLY)	
I (n=4)	SALIVA	GCF
II (n=4)	SALIVA	GCF

Clinical Tooth Movement

Clinical tooth movement was evaluated using standardized magnification-corrected occlusal photographs obtained at baseline, Week 3, and Week 6.

Both aligner systems produced measurable orthodontic tooth movement throughout the study period. However, participants treated with direct 3D-printed aligners demonstrated greater cumulative tooth movement than those treated with thermoformed aligners. By Week 6, the direct 3D-printed aligner group achieved approximately 2.25 mm of tooth movement, whereas the thermoformed aligner group demonstrated approximately 0.9 mm, indicating greater treatment efficiency with direct-printed aligners.

Temporal Expression of MMP-13

MMP-13 concentrations demonstrated dynamic changes following initiation of orthodontic force in both GCF and saliva.

In both treatment groups, GCF consistently exhibited higher MMP-13 concentrations than saliva throughout the observation period. The temporal expression pattern reflected active extracellular matrix remodeling during orthodontic tooth movement.

Participants treated with direct 3D-printed aligners demonstrated greater MMP-13 expression than those treated with thermoformed aligners, suggesting enhanced collagen degradation and periodontal ligament remodeling associated with improved force delivery.

Temporal Expression of ICTP

ICTP concentrations also demonstrated temporal variation throughout orthodontic treatment in both biological fluids.

In the thermoformed aligner group, ICTP levels showed moderate fluctuations over the six-week observation period. In contrast, the direct 3D-printed aligner group demonstrated consistently higher ICTP concentrations, particularly in GCF, indicating increased osteoclastic bone remodeling associated with orthodontic force application. GCF exhibited greater biomarker expression than saliva in both treatment groups.

Comparison of MMP-13 and ICTP Expression

Simultaneous evaluation of MMP-13 and ICTP demonstrated that both biomarkers reflected active periodontal remodeling during orthodontic tooth movement while representing different biological phases of the remodeling process.

MMP-13 predominantly reflected extracellular matrix degradation during the early stages of tissue remodeling, whereas ICTP represented collagen degradation associated with osteoclastic bone resorption. The complementary temporal expression of these biomarkers provided a broader assessment of periodontal remodeling than evaluation of either biomarker alone.

Across all observation periods, direct 3D-printed aligners exhibited greater expression of both biomarkers compared with thermoformed aligners, corresponding with the greater amount of clinical tooth movement observed in the experimental group.

Gingival Crevicular Fluid versus Saliva

Comparison of biological sampling media demonstrated that GCF consistently yielded higher concentrations and more distinct temporal changes for both MMP-13 and ICTP than whole unstimulated saliva.

The localized origin of GCF enabled more sensitive detection of periodontal tissue remodeling, whereas salivary biomarker concentrations were comparatively attenuated because of dilution by whole oral fluids. These findings support the use of GCF as the preferred biological medium for monitoring orthodontic tissue remodeling.

Proposed Biological Model of Periodontal Tissue Remodeling During Orthodontic Tooth MOVEMENT: A DUAL-BIOMARKER APPROACH

Orthodontic Force Application

↓

Mechanical Stress on Periodontal Ligament

↓

Mechanotransduction & Cellular Activation

↓

Release of inflammatory mediators
(IL-1β, TNF-α, IL-6, PGE_2, RANKL, etc.)

↓

Extracellular Matrix (ECM) Remodeling

↓

Matrix Metalloproteinase-13
(MMP-13 Expression)

↓

Collagen Degradation & Periodontal Ligament Remodeling

↓

Osteoclast Recruitment & Activation

↓

Alveolar Bone Resorption & Remodeling

↓

Release of ICTP (Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type I Collagen) into GCF and Saliva

↓

Clinical Orthodontic Tooth Movement

↓

Biomarker Monitoring During Clear Aligner Therapy Dual

Biomarker Strategy
MMP-13 → ECM Remodeling
ICTP → Bone Resorption

Statistical Analysis

Within-group analysis demonstrated significant temporal variation in GCF biomarker concentrations across the observation period, whereas changes in salivary concentrations were comparatively less pronounced. ANOVA identified significant differences in GCF ICTP levels over time in both treatment groups, while salivary ICTP demonstrated limited statistical significance. Similar temporal trends were observed for MMP-13, supporting active periodontal remodeling following orthodontic force application.

Between-group comparisons showed consistently higher biomarker expression in the direct 3D-printed aligner group than in the thermoformed aligner group throughout treatment. Correlation analyses further demonstrated positive associations between biomarker expression and the magnitude of clinical tooth movement, supporting the biological relevance of both MMP-13 and ICTP as indicators of orthodontic tissue remodeling

DISCUSSION

Orthodontic tooth movement (OTM) is a complex biological process involving coordinated periodontal ligament (PDL) remodeling, extracellular matrix (ECM) degradation, and alveolar bone resorption in response to controlled mechanical forces. These events are mediated through a cascade of inflammatory cytokines, matrix metalloproteinases, osteoclasts, osteoblasts, and signaling molecules that regulate tissue remodeling while maintaining periodontal homeostasis. Although several biomarkers have individually been investigated to characterize these biological responses, few studies have simultaneously evaluated biomarkers representing different stages of periodontal remodeling within the same clinical population. The present prospective clinical study therefore adopted a **dual-biomarker** approach, simultaneously evaluating Matrix Metalloproteinase-13 (MMP-13) and Pyridinoline Cross-linked Carboxy-terminal Telopeptide of Type I Collagen (ICTP) in gingival crevicular fluid (GCF) and whole unstimulated saliva (UWS) obtained from the same participants treated with thermoformed and direct 3D-printed clear aligners. This strategy enabled assessment of complementary biological events associated with orthodontic tooth movement rather than relying on a single molecular indicator.[7-11]

The principal finding of the present study was that both MMP-13 and ICTP demonstrated measurable temporal changes throughout the six-week observation period, confirming active periodontal tissue remodeling during orthodontic tooth movement. Both thermoformed and direct 3D-printed aligners induced progressive biological responses; however, the direct 3D-printed aligner group consistently demonstrated greater biomarker expression together with increased clinical tooth movement. These findings suggest that direct 3D-printed aligners may promote a more pronounced biological remodeling response while maintaining the physiological sequence of orthodontic tissue adaptation.[40-]

Matrix metalloproteinases constitute an essential family of zinc-dependent enzymes responsible for degradation of extracellular matrix components during orthodontic tooth movement. Among these enzymes, MMP-13 (collagenase-3) plays a pivotal role because of its high affinity for type I and type III collagen, the principal structural proteins of the periodontal ligament and alveolar bone matrix. Mechanical loading stimulates fibroblasts, osteoblasts, osteocytes, and inflammatory cells to express MMP-13, thereby facilitating collagen degradation, extracellular matrix turnover, and osteoclast recruitment. The increased MMP-13 concentrations observed in the present study are therefore consistent with its established role as an early biomarker of extracellular matrix remodeling during orthodontic tooth movement and corroborate previous investigations demonstrating increased matrix metalloproteinase activity following orthodontic force application.

In contrast, ICTP reflects a later stage of periodontal remodeling. Unlike MMP-13, which functions as an active collagenase, ICTP is released as a degradation product of mature type I collagen during osteoclastic bone resorption. Consequently, ICTP serves as a biochemical marker of alveolar bone turnover rather than enzymatic matrix degradation. The increased ICTP concentrations observed during active orthodontic treatment in the present study are therefore consistent with physiological bone remodeling and agree with previous reports identifying ICTP as a sensitive indicator of bone resorption associated with orthodontic tooth movement.

A major strength of the present investigation lies in the adoption of a **dual-biomarker approach**. Both MMP-13 and ICTP were quantified from aliquots of the same GCF and saliva samples collected from the same participants at identical time intervals, thereby minimizing inter-individual variability and enabling direct comparison of two biologically complementary markers. Rather than representing isolated molecular events, these biomarkers describe sequential phases of periodontal remodeling. MMP-13 primarily reflects extracellular matrix degradation within the periodontal ligament, whereas ICTP reflects collagen breakdown associated with osteoclastic alveolar bone resorption. Simultaneous evaluation of these biomarkers therefore provides a more comprehensive understanding of orthodontic tissue remodeling than assessment of either biomarker alone.

The additional objective of the present study was to determine whether MMP-13 and ICTP exhibit complementary temporal expression patterns during orthodontic tooth movement. Although each biomarker represents a distinct biological process, both demonstrated coordinated temporal changes throughout treatment. These findings support the concept that a **dual-biomarker strategy** may more accurately characterize the biological continuum of orthodontic tooth movement, encompassing both extracellular matrix remodeling and subsequent bone resorption. Such an approach may improve future monitoring of individual biological responses and contribute to the development of precision orthodontics.

Another important observation was the consistently higher concentrations of both biomarkers in gingival crevicular fluid compared with whole unstimulated saliva. 13-16,24 Because GCF originates directly from the periodontal tissues adjacent to the tooth, it reflects localized biological activity occurring at the site of orthodontic force application. In contrast, salivary biomarkers are diluted by secretions from multiple oral sources, thereby reducing their sensitivity for detecting localized periodontal remodeling. Although saliva remains an attractive non-invasive diagnostic fluid because of its ease of collection, the present findings support previous evidence indicating that GCF remains the more sensitive biological medium for evaluating molecular changes associated with orthodontic tooth movement.

The present study also demonstrated greater clinical tooth movement in participants treated with direct 3D-printed aligners than in those treated with thermoformed aligners.41-51 This clinical observation corresponded with greater expression of both MMP-13 and ICTP throughout the observation period. Conventional thermoplastic aligners undergo rapid stress relaxation upon initial activation and intraoral aging52-54, leading to decay in force delivery over time55-57,. In addition, the thermoforming process alters the initial physical and mechanical characteristics of thermoplastic polymers58-59. Direct 3D-printed aligners are fabricated by additive manufacturing without a thermoforming process, thereby maintaining more uniform material thickness and improved geometric accuracy. These characteristics may contribute to more consistent force delivery and consequently enhanced biological remodeling. However, the present study was not designed to evaluate force systems or material mechanics directly, and further biomechanical investigations are required before definitive conclusions regarding the underlying mechanisms can be drawn.

From a clinical perspective, the present findings support the emerging concept of **biologically guided orthodontics.** Although biomarker analysis currently remains primarily a research tool, simultaneous assessment of MMP-13 and ICTP may eventually facilitate individualized monitoring of periodontal tissue remodeling, optimization of aligner change intervals, and early identification of patients exhibiting altered biological responses to orthodontic force. Consequently, the **dual-biomarker approach** proposed in the present study may represent an important step toward personalized clear aligner therapy and precision orthodontics.

The strengths of the present study include its prospective design, standardized treatment protocol, repeated longitudinal sample collection, simultaneous assessment of two complementary biomarkers, comparison of GCF and saliva, and evaluation of both thermoformed and direct 3D-printed aligners within the same clinical framework. Collectively, these methodological features enhance the translational relevance of the findings and provide a comprehensive evaluation of periodontal tissue remodeling during clear aligner therapy.

Nevertheless, several limitations should be acknowledged. The relatively small sample size and six-week observation period limit the generalizability of the findings and restrict evaluation to the early phases of orthodontic tooth movement. Only two biomarkers were investigated despite the complex molecular network involved in periodontal remodeling. Future multicenter studies incorporating larger patient cohorts, longer follow-up periods, additional inflammatory and bone-remodeling biomarkers (such as RANKL, OPG, IL-1β, and TNF-β), together with advanced imaging and biomechanical analyses, are required to further validate the proposed dual-biomarker approach and establish its clinical applicability.

In conclusion, the present study demonstrates that simultaneous evaluation of MMP-13 and ICTP provides complementary information regarding extracellular matrix remodeling and alveolar bone resorption during orthodontic tooth movement. Greater biomarker expression and increased clinical tooth movement observed with direct 3D-printed aligners, together with the superior sensitivity of GCF compared with saliva, support the biological relevance of these findings. Collectively, the results suggest that a dual-biomarker approach combining MMP-13 and ICTP represents a promising strategy for monitoring orthodontic tissue remodeling and provides a foundation for future research into biologically guided, evidence-based, and personalized clear aligner therapy.

CLINICAL IMPLICATIONS

The findings of the present study suggest that the simultaneous evaluation of MMP-13 and ICTP provides a more comprehensive assessment of periodontal tissue remodeling during orthodontic tooth movement than evaluation of either biomarker alone. By reflecting complementary biological processes, namely extracellular matrix remodeling and alveolar bone resorption, this dual-biomarker approach has the potential to improve understanding of individual biological responses to orthodontic force. The greater biomarker expression and increased clinical tooth movement observed in patients treated with direct 3D-printed clear aligners suggest that advances in aligner manufacturing may influence not only mechanical performance but also the biological response of periodontal tissues. Although biomarker analysis is presently confined primarily to research settings, future development of chairside molecular diagnostic technologies may facilitate biologically guided orthodontic treatment, individualized monitoring of tissue remodeling, optimization of aligner change intervals, and ultimately the advancement of precision orthodontics.

LIMITATIONS

The findings of the present study should be interpreted in light of several limitations. The relatively small sample size and short follow-up period limit the generalizability of the results and restrict evaluation to the early phases of orthodontic tooth movement. Only two biomarkers were investigated, whereas periodontal remodeling is regulated by a complex network of inflammatory cytokines, matrix metalloproteinases, signaling molecules, and bone turnover markers. Furthermore, biomarker concentrations were measured at predetermined time intervals, which may not completely reflect the dynamic biological changes occurring throughout treatment. Although greater biomarker expression was associated with increased clinical tooth movement, the present study was not designed to establish causal relationships or investigate the biomechanical characteristics responsible for the observed differences between aligner systems. Future multicenter prospective studies with larger sample sizes, longer observation periods, comprehensive biomarker panels, advanced imaging techniques, and biomechanical analyses are required to validate the proposed dual-biomarker approach and determine its clinical applicability in routine orthodontic practice.

CONCLUSION

Within the limitations of this prospective clinical study, simultaneous evaluation of MMP-13 and ICTP demonstrated that both biomarkers undergo characteristic temporal changes during orthodontic tooth movement, reflecting complementary phases of periodontal tissue remodeling. Patients treated with direct 3D-printed clear aligners exhibited greater biomarker expression and increased clinical tooth movement than those treated with thermoformed aligners, suggesting a more pronounced biological response during treatment. Gingival crevicular fluid proved to be a more sensitive diagnostic medium than whole unstimulated saliva for monitoring localized periodontal remodeling.13-16,24 Collectively, these findings support the concept that a dual-biomarker approach, integrating MMP-13 as a marker of extracellular matrix remodeling and ICTP as a marker of alveolar bone resorption, provides a more comprehensive understanding of the biological events underlying orthodontic tooth movement than assessment of either biomarker alone. Although further large-scale longitudinal studies are required, this approach represents a promising strategy for biologically guided, evidence-based, and personalized clear aligner therapy.

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Generative artificial intelligence in contemporary Orthodontics – from chatbots to agentic co-pilots

Ameet Vaman Revankar B.D.S, MDS

Cert. Healthcare AI (IIIT-H)

Professor Of Orthodontics, SDM College of dental sciences, SDM University, Dharwad, India

Editorial Board Member – BMC oral health (Springer Nature),

EBM -RGUHS journal of dental sciences, RGUHS University, Govt. of Karnataka, India

ABSTRACT:

Artificial Intelligence (AI) applications in orthodontics have evolved from early pattern recognition algorithms to generative AI (GenAI) powered agentic systems that can aid in diagnostic tasks, perform autonomous research and assist in administrative tasks. The transition from GenAI powered chatbots to agentic systems is fueled by the unreliable, hallucinated outputs associated with chatbots that are addressed to a large extent by agentic systems. Agentic systems are rapidly emerging as a reliable aid in these tasks and also surpass human abilities in certain areas such as identification of micro ankylosis and assessment of sutural maturity.

This paper explores the novel applications of GenAI agentic systems in the performance of reliable orthodontic research and diagnostic assistance as clinical copilots.

Emphasizing that 'the future is not AI driven; it is AI augmented,' this paper outlines the role of the Orthodontic Centaur model—a human-led, AI-supported Human in the Loop (HITL) architecture. Furthermore, it highlights the importance of algorithmic governance, ethical oversight, and demographic calibration for South Asian craniofacial phenotypes. The Sri Lanka Orthodontist Society (SLOS) is uniquely positioned to lead regional innovation by fostering AI literacy, establishing a national craniofacial data registry ushering in the AI era of human-led, agentic AI orthodontic excellence.

INTRODUCTION: NAVIGATING THE HYPE CYCLE OF ARTIFICIAL INTELLIGENCE

Digital orthodontics has undergone phenomenal change in the recent years. Intraoral scanning, cone-beam computed tomography (CBCT) and 3D facial photogrammetry have become mainstream diagnostic aids. This change has also led to the increased use of AI in the interpretation/manipulation of data generated by these new modalities. When we ponder at the conceptual Gartner Hype Cycle for AI 1-moving from the peak of inflated expectations through the trough of disillusionment a critical distinction is apparent between early automation, large language model (LLM) GenAI chatbots (such as OpenAI ChatGPT, Google Gemini, Anthropic Claude etc.) and true clinical co-pilots partially represented by agentic systems which I term as clinical artificial intelligence (CAI). (Figure 1)

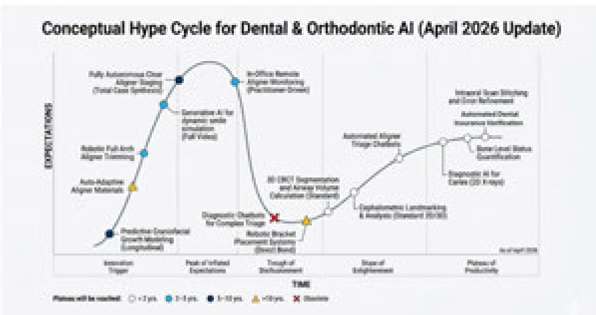

Figure 1: Conceptual Hype Cycle for Dental and Orthodontic AI

Adapted from the Gartner hype cycle 1, this schematic explains the maturity, market expectations, and clinical adoption timelines of current AI technologies. Emerging concepts with high potential but unproven reliability, such as predictive craniofacial growth modelling, lie at the "Innovation Trigger." Hyped technologies like fully autonomous clear aligner staging are at the "Peak of Inflated Expectations," but with estimated 5–10 years timeline to reach mainstream. At the "Slope of Enlightenment" and nearing the "Plateau of Productivity" tools include automated 2D/3D cephalometric landmarking, intraoral scan manipulation, and diagnostic AI for caries. These tools represent already validated and reliable technologies expected to become standard practice within the next two years.

Note: This conceptual diagram was generated with generative Image generation tool Google Nano banana with reference sources and prompts provided and verified by the author for accuracy.

CAI is much more than the simple automated matching of patterns or the probabilistic generation of text. It involves the analysis of multimodal clinical data, correlating 3D DICOM volumes, multi-temporal registration, execution of software steps to perform complex tasks such as virtual surgical planning (VSP).

The Data-Information-Knowledge-Wisdom (DIKW) pyramid is a key concept that is at the center of this AI transformation (Figure 2). Raw CBCT voxel densities and intraoral meshes represent "Data"; organized cephalometric measurements and volumetric renderings yield "Information"; clinical correlations and biomechanical trajectory calculations generate "Knowledge". However, clinical Wisdom, ethics, empathy and decision making unique to the experienced specialist remains exclusively human.

Rather than replacing the clinician, CAI reiterates the need of “The Orthodontic Centaur model” (Fig 2). Similar to the mythical Centaur that combined human intelligence with equine speed, the orthodontic Centaur augments human clinical wisdom, tactile expertise, and diagnostic intuition with the multi-dimensional data processing speed of agentic AI.

Figure 2: Conceptual Framework of the Orthodontist–AI Centaur Model.

The DIKW hierarchy and HITL clinical workflows. Computational AI engine serves as equine body at the Data layer, while the clinician is the director who provides the Information and Knowledge through context, retaining ultimate authority over ethical execution and treatment Wisdom which forms the head of the Centaur.

Note: This conceptual diagram was generated with generative Image generation tool Google Nano banana with reference sources and prompts provided and verified by the author for accuracy.

GENERALIST CHATBOTS V/S AGENTIC AI

Recent literature on the performance of GenAI LLM chatbots on medical tasks have highlighted significant discrepancies in reliability2. When these chatbots are used to diagnose complex cases, formulating treatment plans, they invariably introduce unverified assumptions and hallucinated citations.

To overcome these issues with chatbots, a shift from conversational chatbots to HITL, goal based, tool-equipped agentic workflows is needed.

Unlike a simple chatbot that merely predicts the next token (simplified as word) in the sequence, an agentic AI harness (such as Google Antigravity, VS Code/ Claude code, Eigent etc) is equipped with discrete computational tools—such as DICOM image processors, 3D surface mesh aligners (via model context protocol -MCP), local code execution/ interpretation, and direct Application Programming interface (API) connections to open access scholarly databases like PubMed and OpenAlex. When presented with a goal/ clinical query, an agentic system splits the problem into subgoals, invokes specific analytical tools, verifies the outputs mathematically, and presents the clinician with a fully audited, transparent report. (Figure 3). The system runs autonomously spinning up HITL verified loops of prompts, tools and code till the goal is arrived at.

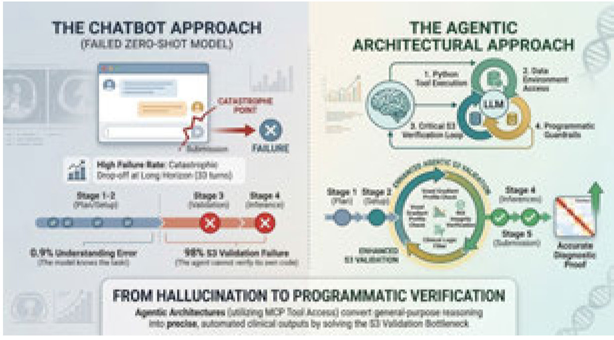

Figure 3: Architectural Comparison of Chat Bots vs. Agentic Workflows in Clinical Diagnostics.

- **Chatbot method (Left):** Standard chatbots exhibit high task understanding but suffer failures across complex diagnostic tasks. The critical failure point occurs at the Stage 3 (S3) or validation phase. Chatbots cannot independently verify outputs prior to submission.
- **The Agentic Architectural Approach (Right):** CAI resolves the validation problem. By utilizing direct tool access (e.g., Model Context Protocol) and necessary guardrails during S3 CAI undergoes mathematical self-verification.

Note: This conceptual diagram was generated with generative Image generation tool Google Nano banana with reference sources and prompts provided and verified by the author for accuracy

The Reality of Clinical Automation:

In healthcare the concept of ‘frictionless, fully automated AI’ is unrealistic and dangerous. HITL agentic systems are the norm in healthcare. The operational reality of clinical AI workflows is accurately captured by the following flowchart:

> ***Prompt breaks → API fails → Agent gets confused → Human steps in → Agent breaks again → Human fixes it → Agent finally works.***

Autonomous HITL agentic systems function as powerful assistants, but human clinical oversight remains the safety net.

CLINICAL APPLICATIONS: VOLUMETRIC DIAGNOSTICS, ANKYLOSIS, AND SUTURAL PROFILING

Properly configured CAI can provide clinical assistance far beyond administrative tasks 5. This assistance should be treated as advice and the clinician shouldn't succumb to cognitive surrender, rather he should evaluate the outputs with scepticism. The relationship between the clinician and the AI copilot should be treated as that with a colleague, where the interaction is more of a discussion until final conclusion is arrived at by the clinician.

Table 1 highlights the different applications of CAI in orthodontics that the author has developed at the time of writing this paper. It should be noted that the applications are not limited to those listed in the table and are open to development of new workflows by the author and the readers.

Table 1 Operational evolution from conventional orthodontic workflows to GenAI LLM chatbots and Agentic CAI.

Operational Vector	Conventional Workflow	Generalist LLMs / Chatbots	Agentic CAI
Diagnostic Processing	Manual 2D cephalometric tracing & visual CBCT slice inspection.	Text prompt processing; unable to inspect raw 3D DICOM voxel arrays directly.	Direct 3D DICOM voxel sweeps, obliquity-corrected reslicing & gradient magnitude mapping.
Ankylosis & Sutural Audit	Qualitative visual appraisal of radiolucency; high missed rate.	Descriptive text summaries based on user-entered clinical notes.	Quantitative line-probe voxel density profiling
Literature Synthesis	Manual PubMed keyword searching; time-intensive charting.	Probabilistic text generation; prone to hallucinated citations & fake DOIs.	Agentic MCP server queries to PubMed/OpenAlex with deterministic PICO extraction & zero hallucination.
Craniofacial Superimposition	Manual 2D landmark superposition on tracing paper.	N/A (cannot perform geometric mesh operations).	2-time-point 3D registration combining 3D meshes
Virtual surgical planning	Mock surgery on articulator mounted plaster models	N/A	Can perform automated multistep procedures after learning from media sources

ANKYLOSIS DETECTION VIA GRADIENT MAGNITUDE MAPPING

Historically the diagnosis of ankylosis of impacted teeth (eg. maxillary canines) has been a blind spot 3. Conventional 2D radiographs and static 3D CBCT axial slices often fail to detect ankylosis due to factors such as slice thickness and also limitations of human senses. This leads to false negatives and long standing failed attempts of tractioning these teeth which is associated with loss of time, money as well as resorption of adjacent teeth and periodontal complications.

Agentic systems can be helpful in this endeavour of detecting micro ankylosis utilising methods such as gradient magnitude mapping wherein gradient differences between the PDL, bone, and cementum are assessed by running python code snippets generated by the CAI. (Figure 4)

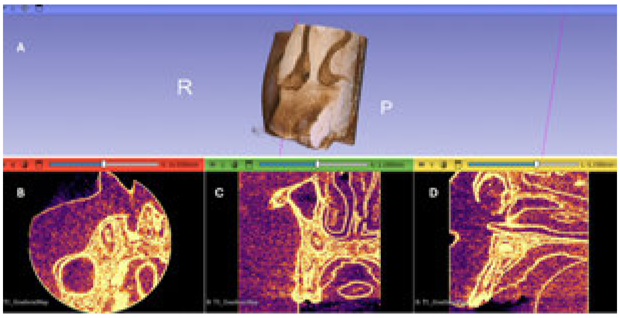

Figure 4: Multi-planar reconstruction of CBCT using automated gradient mapping

Axial (B), coronal (C), and sagittal (D) tomographic slices display a processed volume (T1_GradientMap) generated via a SimpleITK (insight tool kit) gradient magnitude image filter. Pseudo-color mapping applied to achieve chromatic density enhancement, enabling delineation of voxel density changes across bone, cementum and PDL for easy identification of micro ankylosis. Image A denotes 3D rendered volume of the same.

Voxel Density Profiling of Midpalatal & Circummaxillary Sutures

In the treatment of skeletal class III malocclusion with maxillary protraction and palatal expansion the assessment of the interdigitation of the circummaxillary sutures is a difficult task 4. Agentic systems can objectively asses sutural maturation and disarticulation on CBCT data.

Using automated line-probe voxel density sweeps across key circummaxillary sutures, this method ensures mathematical calculation of the sutural status and thus help in this decision.

Autonomous 2 time point superimposition of 3 D data

Superimposition of 3D data across different time points autonomously can be delegated to agentic systems to map differences in teeth position, bone position etc. These systems utilise rigid registration and heat maps to deliver accurate diagnostic outputs at unprecedented speed (Fig. 5)

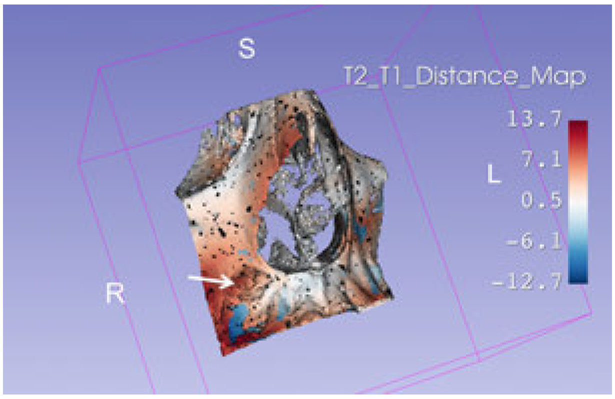

Figure 5: Heatmap of 2 time point CBCT superimposition (autonomous) in canine impaction

Quantitative surface distance map comparing baseline (T1) and 1.8-year post-traction (T2) CBCT. Neutral white/grey shading (across the hard palate and nasal floor indicates exact anatomical match (0-0.5mm difference) indicating registration accuracy on stable reference bone. Red zones (+0.5 to +13.7 mm) indicate outward surface change (apposition), while blue zones (-0.5mm to 12.7 mm) denote inward surface change (resorption). Confirms zero movement of the impacted canine (white arrow) after 18 months of active traction due to micro-ankylosis

Autonomously performing of multistep virtual surgical planning

Agentic systems can learn multistep software steps from media such as Youtube videos and then apply the learning on our datasets and perform complex multistep workflows such as VSP (Fig 6)

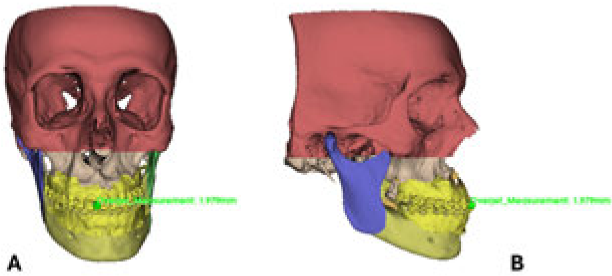

Figure 6: Virtual Surgical Planning (VSP) of a bimaxillary orthognathic procedure.

(A) Frontal and (B) right lateral 3D reconstructions illustrating the postoperative skeletal rendering. The workflow shows autonomous CAI CBCT virtual osteotomies demonstrating a Le Fort I advancement (+6 mm) combined with a BSSO setback (−5 mm with 2.0° clockwise mandibular autorotation), maintaining stationary condylar reference. A final positive incisal overjet of 1.98 mm (annotated) is achieved from a baseline skeletal Class III relationship with reverse overjet.

Dark Red: Stable cranial base serving as the stationary reference frame.
Salmon / Off-White: Mobilized Le Fort I maxillary segment registered with the maxillary intraoral scan.
Yellow: Mobilized distal mandibular segment incorporating the mandibular intraoral scan.
Blue & Green: Stationary right (blue) and left (green) proximal condylar-ramal segments maintained in their anatomical positions.

AI GOVERNANCE, ETHICS, AND SOUTH ASIAN DEMOGRAPHIC CALIBRATION

Artificial Intelligence offers unprecedented computational speed, however the same should be regulated and governance frameworks established.

1. Demographic Calibration : The majority of AI models are calibrated on Caucasian , Hispanic, American or Chinese datasets which leads to algorithmic bias when applied to South Asian populations including Sri Lankan demography. Srilankan population exhibit unique morphometric characteristics, such as higher rates of bimaxillary proclination and distinct soft-tissue thick-lip profiles. Therefore local data calibration of AI models is mandatory.
2. On-Device Data Privacy: Priority should be given to on device AI models in case of healthcare data because this data falls under protected health information category. In case of the use of on cloud intelligence via API calls, proper safeguards should be in place including the primary need for a non disclosure agreement with the service provider.
3. For Clinical validation rider: Agentic tools are computational aids. Every AI-generated diagnostic report or assessment should be considered as an advise and should be subject to explicit human specialist review.

CALL TO ACTION FOR THE SRI LANKAN ORTHODONTIC SOCIETY

The SLOS is strategically positioned to pioneer regional digital revolution across south Asia. With its rich heritage of scientific leadership in clinical orthodontics SLOS can foster new innovation as CAI reshapes global orthodontics.

AI implementation in the field of orthodontics has to be undertaken on the following pillars

Pillar 1: Introduce a formal AI literacy program in the Postgraduate curriculum – Include Practical instructions I digital technology, responsible AI HITL automation in the post graduate program.

Pillar 2: Establishing a national craniofacial data registry – of Srilankan CBCT datasets, intraoral scans and facial photogrammetry. This will serve as the data centre for future training of customised AI models.

Pillar 3: Initiate multicentric trails of CAI- to assess the efficacy and reliability of this approach in assisting diagnosis and treatment planning

CONCLUSION

Machine learning AI models remain the gold standard in diagnosis and treatment planning however they have to be developed from scratch which require a large amount of data, labelling as well as specialised programmers to develop.

Agentic CAI is universally available. It requires customisation and proper execution to output a reliable result. It is a force multiplier to the orthodontist's ingenuity. The combination of human clinical wisdom and AI processing power "the orthodontic Centaur" is the right way forward.

The principle remains clear: technology must serve as the instrument, but human care, empathy, and clinical excellence must always remain the master.

Disclosure: *Generative image generation tool Google Nano Banana has been used in designing non data conceptual schematics/ illustrations (Fig 1-3). The underlying theoretical concepts, sources, prompts were entirely designed and verified by the author. No patient raw data/ radiographic images have been generated/altered/edited using AI.*

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Orthodontic camouflage of a borderline skeletal Class III malocclusion in a growing patient: A case report and review of the literature

H.G.P. Miyuranga[1], V.S.N. Vithanaarachchi[2], H.S.K. Rathnatilake[3], Dr WBMCRD Weerasekera[4]

[1]Registrar in Orthodontics, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

[2]Professor in Orthodontics, Division of Orthodontics, Department of Community Dental Health, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

[3]Senior Lecturer, Division of Orthodontics, Department of Community Dental Health, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

[4]Senior Lecturer, Division of Orthodontics, Department of Community Dental Health, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

ABSTRACT:

Class III malocclusion presents a significant diagnostic and therapeutic challenge because treatment outcomes are influenced by the severity of the skeletal discrepancy, residual growth potential and the limits of dentoalveolar compensation. Appropriate case selection is therefore essential when considering orthodontic camouflage as an alternative to orthognathic surgery. This report describes the management of a 14 year old female who presented with a Class III malocclusion on a mild skeletal Class III base, complicated by moderate maxillary crowding, mild mandibular crowding and bilateral palatally displaced maxillary lateral incisors. Clinical examination revealed a straight facial profile, competent lips and average vertical skeletal proportions. Fixed appliance treatment was undertaken using preadjusted edgewise appliances with MBT prescription without extractions. Space was obtained through arch development, limited interproximal reduction and controlled alignment mechanics. The palatally displaced lateral incisors were aligned using open coil springs, piggyback nickel titanium archwires, and inverted bracket positioning. Light Class III elastics were used during the finishing stage. Active treatment was completed over 34 months. At completion, a Class I incisor relationship, normal overjet and overbite, improved smile aesthetics and satisfactory buccal interdigitation were achieved. The Peer Assessment Rating score improved from 41 to 1, representing a 97.6% reduction. Cephalometric evaluation demonstrated maintenance of the skeletal relationship with correction achieved primarily through dentoalveolar adaptation. This case illustrates that carefully selected adolescent patients with mild skeletal Class III discrepancies may be successfully managed using non extraction orthodontic camouflage while preserving future treatment options should unfavourable growth occur.

Keywords: Class III malocclusion, orthodontic camouflage, non extraction treatment, adolescent orthodontics, dentoalveolar compensation.

INTRODUCTION

Management of Class III malocclusion remains one of the most challenging areas in orthodontics because of its multifactorial aetiology, variable growth pattern and potential impact on facial aesthetics and function. The discrepancy may result from mandibular prognathism, maxillary deficiency, or a combination of both skeletal components, often accompanied by dentoalveolar compensations that mask the severity of the underlying skeletal relationship.[1]

Treatment options for Class III malocclusion include growth modification, orthodontic camouflage and combined orthodontic surgical treatment. While severe skeletal discrepancies are commonly managed surgically, the optimal management of borderline cases remains controversial. In such patients, the distinction between orthodontic camouflage and surgical correction is often less clear and requires careful assessment of skeletal relationships, facial aesthetics, growth status and patient expectations.[2]

Orthodontic camouflage aims to improve occlusal relationships and dental aesthetics through dentoalveolar adaptation while accepting the underlying skeletal discrepancy. Previous investigations have attempted to define the limits of this approach. Troy et al. reported that patients successfully treated with camouflage generally exhibited less severe skeletal discrepancies than those selected for orthognathic surgery.[3] Similarly, Burns et al. demonstrated that favourable outcomes are most frequently achieved in patients with mild skeletal Class III relationships, acceptable facial profiles and sufficient potential for dentoalveolar compensation.[4] Consequently, successful camouflage treatment depends not only on cephalometric findings but also on the clinician's ability to assess facial balance, growth potential and the biological limits of tooth movement.

Treatment planning becomes particularly challenging in adolescent patients who have not yet completed craniofacial growth. Residual mandibular growth may compromise treatment stability and influence the long term outcome of camouflage therapy. Although skeletal maturity indicators such as cervical vertebral maturation provide useful information regarding growth status, accurate prediction of future mandibular growth remains difficult.[5] As a result, treatment decisions in growing patients must balance the benefits of intervention against the uncertainty associated with continued skeletal development.

This report describes the non extraction orthodontic management of an adolescent female presenting with a borderline skeletal Class III malocclusion complicated by bilateral palatally displaced maxillary lateral incisors. The rationale for treatment selection, treatment outcome and relevant evidence from the literature are discussed.

CASE REPORT

A 14 year old female presented to the orthodontic clinic with the chief complaint of irregularly positioned upper front teeth. She was medically fit and well with no relevant medical history. Family history was non contributory and there was no known history of Class III skeletal pattern among immediate relatives. The patient was a school student and demonstrated satisfactory motivation towards orthodontic treatment.

Extra oral examination revealed a symmetrical face with balanced facial proportions and a straight profile. Lip competence was present at rest and vertical facial proportions were average. Smile aesthetics were compromised by irregular alignment of the maxillary anterior teeth and the presence of dark buccal corridors (Figure 1). Temporomandibular joint examination was unremarkable and mandibular function was normal.

Intra oral examination demonstrated permanent dentition with satisfactory oral hygiene. The maxillary arch was tapered in form and exhibited moderate anterior crowding. Both maxillary lateral incisors were positioned palatally and the left maxillary central incisor was rotated. The mandibular arch was ovoid with mild crowding and retroclined lower incisors. The incisor relationship was Class III with an overjet of 1 mm and a reduced overbite. The upper dental midline coincided with the facial midline, while the lower dental midline was deviated 1 mm to the right. Bilateral quarter unit Class III molar relationships were present. The left canine relationship was Class I and the right canine relationship was quarter unit Class II. Anterior crossbites involving both maxillary lateral incisors were evident (Figure 2).

(a) (b) (c) (d)

Figure 1 – pre treatment photographs – Extra Oral

(a) (b) (c)

(d) (e)

Figure 1 – pre treatment photographs – Inter Oral

PRE-TREATMENT RADIOGRAPHS:

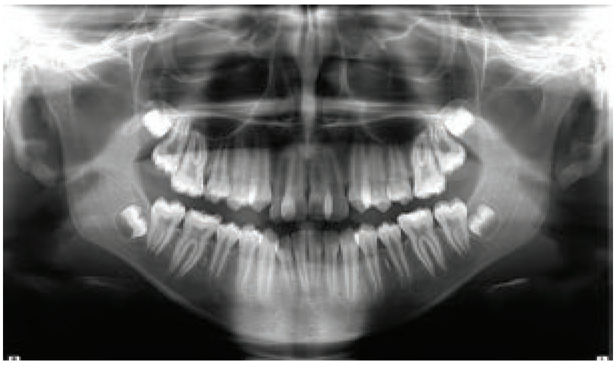


Figure 3 - Dental Panoramic Tomogram

Figure 3 - IOPA 21 12

Figure 5. Lateral cephalogram

VARIABLE	PRE TREATMENT	POST TREATMENT	CHANGE
SNA	85°	85°	0°
SNB	84°	84°	0°
ANB	1°	1°	0°
SN to maxillary plane	10°	11°	+1°
Wits appraisal	-5mm	-4mm	+1mm
Upper incisor to maxillary plane angel	114°	115°	+1°
Lower incisor to mandibular plane angel	76°	84°	+8°
Interincisal angle	143°	136°	-7°
Edge-centroid relationship	+3mm	+2mm	-1mm
Maxillary mandibular planes angel (MMA)	27°	27°	0°
Upper anterior face height	50mm	51mm	+1mm
Lower anterior face height	62mm	65mm	+3mm
Face height ratio	55%	56%	+1%mm
Lower incrsor to A-Po Line	0mm	+2mm	+2mm
Lower lip to Ricketts E Plane	-2mm	-2mm	0mm
Naso labial angel	95°	95°	0°
CVM	4	5	

Table 1. Cephalometric changes following treatment

Panoramic radiography demonstrated developing third molars without evidence of pathology, root resorption or significant dental anomalies (Figure 3). Cephalometric analysis revealed a mild skeletal Class III relationship with an SNA angle of 85°, SNB angle of 84° and ANB angle of 1°. Wits appraisal was −5 mm. Vertical skeletal proportions were within normal limits with a maxillary mandibular planes angle of 27°. The upper incisors were mildly proclined at 114°, while the lower incisors were retroclined at 76°, indicating dentoalveolar compensation for the underlying skeletal discrepancy. Cervical vertebral maturation assessment indicated stage 4 skeletal maturity(Figure 4)(Table 1).

A diagnosis of Class III malocclusion on a mild skeletal Class III base with average vertical skeletal proportions was made. The malocclusion was complicated by moderate maxillary crowding, mild mandibular crowding and bilateral palatally displaced maxillary lateral incisors.

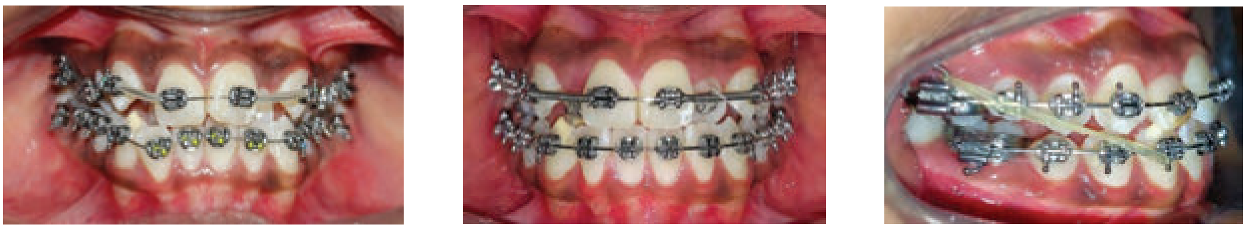
The treatment objectives were to align the dentition, relieve crowding, correct the anterior crossbites, establish a functional incisor relationship with normal overjet and overbite, improve smile aesthetics and maintain facial balance. Following discussion of treatment alternatives, a non extraction camouflage approach was selected. The patient and her parents were informed of the possibility of future mandibular growth and the limitations associated with orthodontic camouflage treatment.

Treatment was undertaken using upper and lower preadjusted edgewise appliances with MBT prescription and a 0.022 × 0.028 inch slot. Initial alignment was achieved using sequential nickel titanium archwires. Because of their severe palatal displacement, the maxillary lateral incisors were excluded from the initial alignment phase (Figure 6). Following progression to a rigid 0.019 × 0.025 inch stainless steel base archwire, nickel titanium open coil springs were placed between the central incisors and canines to create space for alignment of the lateral incisors (Figure 6b). The lateral incisors were subsequently bonded using inverted bracket positioning to improve torque control. Elastic thread traction and piggyback nickel titanium mechanics were used to guide the teeth into the arch. Posterior Glass Ionomer bite blocks were placed temporarily to facilitate correction of the anterior crossbites.

After alignment stage, limited interproximal enamel reduction was carried out in selected areas to assist space management and midline correction. Light Class III elastics were introduced during the finishing stage to improve sagittal relationships and achieve satisfactory intercuspation (Figure 6c). Final detailing was completed using Stainless Steel and Titanium Molybdenum alloy archwires with appropriate finishing bends.

Active treatment was completed over a period of 24 months. At debonding, a Class I incisor relationship with a 2 mm overjet and average overbite had been established. Bilateral Class I molar relationships and a left Class I canine relationship were achieved, while the right canine relationship remained quarter unit Class II (Figure 9). The anterior crossbites were corrected and smile aesthetics improved considerably (Figure 8). The Peer Assessment Rating score improved from 41 to 1, representing a 97.6% reduction. Post treatment radiographs demonstrated satisfactory root positions without clinically significant root resorption. Retention consisted of a maxillary bonded retainer supplemented by a Hawley retainer and a mandibular bonded retainer extending from premolar to premolar.

Figure 6. MID-TREATMENT PHOTOGRAPHS

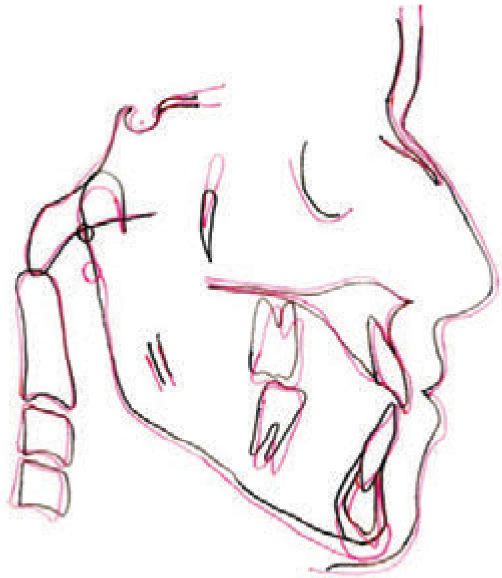


(a) (b) (c)

Figure 7. NEAR END ORTHODONTIC TREATMENT RADIOGRAPHS

(a)

(b)



(c)

Pre and Post Cephalogram superimposition

Figure 8. POST-TREATMENT PHOTOGRAPHS: EXTRA-ORAL

Figure 9. POST-TREATMENT PHOTOGRAPHS: INTRA-ORAL

DISCUSSION

Management of borderline skeletal Class III malocclusion remains one of the most debated areas in contemporary orthodontics. Although severe skeletal discrepancies are generally treated with orthognathic surgery, the optimal management of patients presenting with mild skeletal disharmony is less clear. In such cases, treatment decisions are influenced by a combination of skeletal findings, facial aesthetics, growth potential, patient expectations and the anticipated stability of the result. Consequently, successful treatment relies not only on accurate diagnosis but also on careful identification of patients who are likely to benefit from orthodontic camouflage.

Several studies have attempted to define the limits of camouflage treatment in Class III malocclusion. Troy et al. compared patients treated by orthodontic camouflage with those managed surgically and found that individuals selected for camouflage generally exhibited less severe skeletal discrepancies and more favourable facial profiles than those treated surgically.[3] Similarly, Burns et al. reported that successful camouflage treatment is most frequently achieved in patients with mild skeletal Class III relationships, acceptable facial aesthetics and sufficient scope for dentoalveolar adaptation.[4] These findings support the treatment approach adopted in the present case. Although the patient exhibited a skeletal Class III relationship with an ANB angle of 1° and a Wits appraisal of –5 mm, facial balance was favourable and the chief complaint related primarily to dental appearance rather than facial aesthetics. The treatment objective was therefore to improve occlusion and smile aesthetics without attempting to eliminate the underlying skeletal discrepancy.

An important consideration during treatment planning was the patient's stage of skeletal development. At the start of treatment, cervical vertebral maturation assessment indicated CVM stage 4, suggesting that peak mandibular growth had recently occurred but residual growth remained possible. Growth prediction remains a major challenge in Class III patients because mandibular development may continue beyond the pubertal growth spurt and influence long term treatment stability. Ngan and Moon highlighted that continued mandibular growth remains one of the principal causes of relapse following orthodontic correction of Class III malocclusion.[2] Although skeletal maturity indicators provide useful information regarding growth status, systematic reviews have demonstrated that their ability to predict the magnitude of future growth is limited.[6] Consequently, treatment planning in growing Class III patients must acknowledge a degree of uncertainty.

The decision to commence treatment before completion of growth was influenced by several factors. The skeletal discrepancy was relatively mild, facial aesthetics were acceptable and the patient expressed concern regarding the appearance of the maxillary anterior teeth during adolescence. Delaying treatment would not necessarily have altered the underlying growth pattern but would have prolonged the psychosocial impact associated with the malocclusion. Rather than attempting to achieve skeletal correction, treatment objectives focused on establishing a functional occlusion, improving smile aesthetics and maintaining future treatment flexibility should unfavourable growth occur.

The choice between extraction and non extraction treatment represented another important aspect of treatment planning. Extraction therapy has traditionally been advocated when significant crowding exists or when greater dentoalveolar compensation is required to camouflage the skeletal discrepancy. However, extraction decisions in Class III patients should not be based solely on space requirements. Proffit et al. emphasised that facial aesthetics, periodontal considerations and the biological limits of tooth movement must also be considered.[1] Excessive dental compensation may place teeth outside the alveolar housing and compromise both periodontal health and long term stability.

In the present patient, moderate maxillary crowding and mild mandibular crowding were managed through arch development, controlled alignment mechanics and limited interproximal enamel reduction. Furthermore, a non extraction approach preserved future treatment options. In growing patients, the possibility of future orthognathic surgery cannot be completely excluded if mandibular growth progresses unfavourably. Previous extraction therapy may increase the extent of orthodontic decompensation required before surgery and complicate subsequent management. Preservation of future treatment options was therefore considered alongside space requirements when selecting the treatment approach.

The outcome achieved in this patient is consistent with previous reports describing successful camouflage of mild skeletal Class III malocclusion through dentoalveolar adaptation. Janson et al. demonstrated that correction of mild Class III relationships is frequently achieved through controlled modification of incisor position rather than skeletal change.[7] In the present case, cephalometric analysis demonstrated no significant alteration in the skeletal relationship during treatment. ANB remained unchanged at 1°, while Wits appraisal improved only slightly. Improvement was therefore achieved primarily through alignment of the maxillary dentition and modification of incisor relationships rather than through skeletal effects.

The lower incisors deserve particular attention because they frequently determine the limits of camouflage treatment. Prior to treatment, the mandibular incisors were retroclined, reflecting natural dentoalveolar compensation for the underlying skeletal discrepancy. Following treatment, lower incisor inclination increased from 76° to 84°, approaching accepted norms while remaining within acceptable biological limits. This finding suggests that treatment achieved partial normalisation of the dentition rather than excessive compensation. Maintenance of lower incisor position within the alveolar envelope is important because excessive proclination or retroclination may compromise periodontal support and increase the likelihood of relapse.

The management of the palatally displaced maxillary lateral incisors represented an additional challenge. Palatal displacement of incisors often requires careful space creation and torque control to avoid undesirable root positioning and periodontal complications. Space was created using open coil springs placed on a rigid base archwire before engagement of the lateral incisors. This approach minimised distortion of the archwire and allowed controlled alignment. Inverted bracket positioning was used to improve torque expression and facilitate correction of root position. Similar biomechanical approaches have been recommended when aligning severely displaced incisors because they permit controlled force application while reducing the risk of adverse effects associated with heavy continuous forces.[8]

Retention remains an important consideration in all Class III cases. Residual growth, soft tissue adaptation and periodontal remodelling may influence stability long after appliance removal. Previous studies have reported that favourable overjet, overbite and intercuspation contribute positively to stability following camouflage treatment.[9] In the present case, bonded retainers were provided in both arches and supplemented by a removable maxillary retainer because of the correction of palatally displaced lateral incisors. Continued long term review remains necessary because growth related changes may continue after completion of active treatment.

This case illustrates that carefully selected patients with mild skeletal Class III discrepancies can be managed successfully with orthodontic camouflage. The favourable outcome was achieved through appropriate case selection, realistic treatment objectives and controlled dentoalveolar adaptation rather than aggressive compensation. While long term monitoring remains essential, the findings support the role of non extraction camouflage as a valid treatment option in selected growing Class III patients.

CONCLUSION

Orthodontic management of borderline skeletal Class III malocclusion requires careful assessment of skeletal relationships, facial aesthetics, growth potential and the biological limits of dentoalveolar compensation. The patient presented in this report exhibited a mild skeletal Class III discrepancy with favourable facial characteristics and moderate space requirements, making orthodontic camouflage a suitable treatment option. A non extraction approach successfully relieved crowding, aligned the palatally displaced maxillary lateral incisors and established a functional occlusion while maintaining facial balance. Treatment correction was achieved primarily through dentoalveolar adaptation rather than skeletal modification. Although long term monitoring remains necessary because of the potential influence of residual mandibular growth, the favourable outcome observed in this case supports the use of non extraction orthodontic camouflage in carefully selected adolescent patients with mild skeletal Class III malocclusion.

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Patient perceptions on undergoing orthodontic treatment amidst the economic crisis in Sri Lanka.

Ariyaratne A[1], Rodrigo T M A[2], Wettasinghe D P[3], Jayasinghe R D[4], Ratnayake N[5]

[1]Senior Registrar in Orthodontics, National Hospital, Kandy, Sri Lanka

[2]Senior Registrar in Orthodontics, National Hospital, Kandy, Sri Lanka

[3]Consultant Orthodontist, National Hospital, Kandy, Sri Lanka

[4]Chair Professor of Oral Medicine and Periodontology, Dept. of Oral Medicine and Periodontology, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

[5]Consultant in Community Dentistry, Institute of Oral Health, Maharagama, Sri Lanka

ABSTRACT:

The financial downturn in 2022 in Sri Lanka substantially affected the healthcare system, yet limited evidence exists on its influence within the field of orthodontics. This study investigated patient perceptions toward undergoing orthodontic treatment amidst the recent economic crisis in Sri Lanka.

A descriptive cross-sectional questionnaire survey was conducted among patients awaiting orthodontic treatment at orthodontic unit, National Hospital Kandy.

Of the sample, 74.7% consisted of adolescent patients with a mean age of 16.93 +/- 4. Significant proportion of patients (42.6%) had an impression that drugs, dental materials and investigations were in short supply in the government hospital, but the clinics can function without disturbances. Almost 58% of patients were willing to spend money on drugs, dental materials or investigations to be taken from the private sector, if they are unavailable currently at the National Hospital. Nearly 51% of patients could afford to spend less than Rs.2000 on drugs, dental materials or investigations if outsourced.

Although many patients sought treatment for aesthetic reasons, financial hardship, material shortages, and travel expenses created major barriers to continuing care. Despite Sri Lanka's free public healthcare system, the need to outsource materials and investigations has increased patients' out-of-pocket costs, highlighting hidden inequities in access. Sustainable solutions—such as implementing a treatment prioritization index, improving resource availability, and offering targeted support for low-income patients—are essential to maintain continued orthodontic services during economic instability.

Keywords: orthodontic treatment, patient perception, economic crisis, Sri Lanka, healthcare affordability

INTRODUCTION

The economic crisis in Sri Lanka, which began in 2022, has had far-reaching and catastrophic impact on various sectors, including healthcare (1). According to the World Health Organization, Sri Lanka's economic crisis rapidly turned into a health crisis amid growing shortages of basic drugs and medical supplies. It is more so as most drugs and almost all medical supplies including equipment are imported. The annual budget estimate for importing medicines and surgical consumables is USD 300 million; only USD 80 million was available for 2023, mostly through donors. As of January 2023, Sri Lanka faced a funding gap of USD 220 million to import essential medicines and supplies (2).

Past global experiences show that a collapse in the economy jeopardizes the health and health system performance by increasing public demand while making access to health care more difficult at the same time (1). Literature indicates that with rising financial burden and fiscal pressure on the public, spending on health per person has reduced significantly. Moreover, there has been a substantial reduction in government commitment to public health. However, increased demand for publicly financed health services can be seen during these times due to the unaffordability of private health care (1). This leads to lower health system capacity, including planning, purchasing of medicines and equipment, and health care delivery. This would, in turn, lead to a higher burden of out-of-pocket expenditure on the public (2).

The financial crisis has affected the entire health sector, including dental care leading to shortages of essential supplies, including medical equipment, medications and materials (3). The economic downturn has led to significant challenges in the healthcare sector, including reduced accessibility and affordability of treatments, scarcity of resources, and disruptions in dental education and training programs (3, 4). Lack of quality materials, special investigations, equipment and technical support has become a major obstacle in providing quality Orthodontic care to the public of Sri Lanka.

Oral health plays a vital role in individuals' physical, mental, social, and economic well-being. (Reference?) Oral health-related quality of life (OHRQoL) is a multidimensional concept that deals with the impact of poor oral health or disease on the performance of activities of daily living, well-being and quality of life (5). Orthodontic treatment is closely linked to oral health-related quality of life (OHRQoL) and plays a pivotal role in enhancing oral health, self-esteem, and overall quality of life. Some of the main reasons for seeking orthodontic treatment are related to the benefits of aesthetics, oral-facial functionality, and psychosocial well-being (6). While malocclusion is neither a disease nor a lethal ailment, orthodontic treatment has a positive psychological impact, as there is a significant improvement in self-esteem and social interaction of the individuals, consequently resulting an apparent demand for orthodontic treatment.

Access to such specialized dental care is often influenced by socioeconomic factors, The economic crisis has exacerbated existing disparities in healthcare access, with many patients prioritizing essential medical needs over elective procedures like orthodontics (4). Additionally, the rising costs of dental materials and treatments, coupled with reduced disposable income, have further limited access to orthodontic care (3). Despite these barriers, orthodontic treatment remains a significant aspiration for many, driven by its potential to improve oral function, aesthetics, and psychosocial well-being (7).

Amidst these challenges, understanding the patient's perspective on receiving orthodontic treatment becomes crucial. While existing research has highlighted the financial and operational impacts of economic crises on healthcare systems, there is a paucity of studies focusing on how patients perceive and navigate orthodontic care during such times(8). This study aims to fill this gap by exploring the experiences, challenges, and expectations of patients seeking orthodontic treatment in Sri Lanka during the economic crisis in 2022-2024.

This research seeks to describe the socio-demographic characteristics of patients attending for orthodontic treatment at the Orthodontic Unit, National Hospital, Kandy and aims to provide a comprehensive understanding of the perceptions on undergoing orthodontic treatment amidst economic crisis in Sri Lanka among patients attending for orthodontic treatment at Orthodontic Unit, National Hospital, Kandy. By shedding light on these perspectives, the study aims to inform policymakers, healthcare providers, and orthodontic practitioners on strategies to improve access and delivery of orthodontic care during economic crises. Ultimately, this research contributes to the broader discourse on healthcare equity and resilience in the face of economic adversity which can be used in planning for the future challenges.

METHODOLOGY

A descriptive cross-sectional study was conducted at the Orthodontic unit, National Hospital, Kandy, from 1st March 2024 to 31st May 2024.

Patients registered for orthodontic treatment at Orthodontic Unit National Hospital Kandy were included in the study and these patients had undergone the initial screening and oral hygiene improvement and waitlisted to start active orthodontic treatment. Patients with hearing and speaking disabilities, psychological disorders were excluded.

Purposive sampling technique was used in this study. Sample size calculation was done using the standard formula for population proportions (11). As there were no Sri Lankan studies on patient perceptions on undergoing orthodontic treatment under special circumstances such as financial crises, patients with positive perceptions considered to be 50% for the purpose of calculating the sample size. Accordingly, the minimum sample size required for the present study, using a prevalence estimate of 50% for positive perceptions at the 95% level of confidence and accepting a sampling error of 5%, was 384.

Ethical clearance was obtained from the Ethical Review Committee of the National Hospital, Kandy (NHK/ERC/66/2023). Study objectives, expected outcomes, advantages, benefits and implementations were clearly explained to the patients and informed written consent was obtained from all the participants/ parents if the patient is was below 18 years.

The study instrument used for the data collection in this study was a self-administered questionnaire and the questionnaire was designed according to the recent literature and expert opinion. Participants' names and other personal details regarding their identity were not collected for the study to ensure confidentiality. If the patient is of below the age of 16, the parent or guardian were instructed to fill the questionnaire. Information obtained were entered into a spread sheet.

STATISTICAL ANALYSIS

All the collected data were checked for their completeness, accuracy and internal consistency to exclude inconsistent data. Statistical analysis was done by using SPSS version 26 (SPSS inc., Armonk, NY, USA) software for windows.

RESULTS

<10 years - Child

10-19 - Adolescence

20-35 – Young adults

>35 – Adult

	Frequency (n)	Percentage (%)
<10 years	5	1.3
10-19 years	278	74.7
20 - 35 years	87	23.4
>35 years	2	0.5

Table 1 - Age distribution of patients registered for orthodontic treatment at orthodontic unit, NHK

A total of 372 patients were included in this study. The age of patients in the sample ranged from 8 to 36 years with a mean age 16.93 +/- 4.066. For ease of data analysis and presentation the patients' age in the sample was categorized into the following age groups.

	Frequency (n)	Percentage (%)
Students	295	78.5
Undergraduate	31	8.3
Unemployed	34	9.1
Employed	15	4.0

Table 2 – Distribution of the employment status in patients registered for orthodontic treatment at orthodontic unit, NHK

Sixty four percent (64%) of the patients in the sample were females giving a female to male ratio of 16:9

A vast majority of the sample were students (78.5%) of which 8.3% were undergraduate students while 4% of the sample were employed and 9% of the sample were unemployed.

	Frequency (n)	Percentage (%)
Less than Rs. 35000	156	41.9
Rs. 35000 to 50000	152	40.9
Rs. 50000 to 100000	50	13.4
More than Rs. 100000	14	3.8

Table 3 - Monthly income of families of patients registered for orthodontic treatment at orthodontic unit NHK

Nearly 42% (n = 156) of the sample had a monthly family income of less than Rs. 35000 while 40.9% had a monthly family income of Rs. 35000 – 50000. The monthly family income was Rs. 50000 to 100000 in 13.4% of patients and more than Rs. 100000 in 3.8% of the sample.

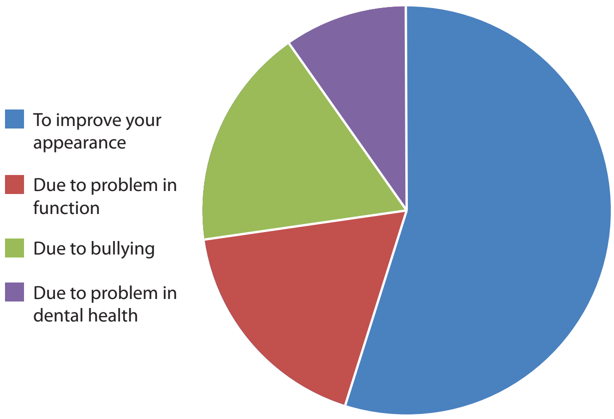

Figure 1 - The reason for treatment in patients registered for orthodontic treatment at orthodontic unit, NHK

Most prevalent reason for seeking orthodontic treatment was to improve the appearance (54.8%). Bullying and psychosocial impact were the reasons for seeking orthodontic treatment for 18% while 16.7% of patients decided to seek treatment due to functional defects. Further 10.5% sought treatment due to problems related to dental health.

	Frequency (n)	Percentage (%)
< 3 months	226	71.5
4 - 6 months	72	19.4
7 - 12 months	31	8.3
25 - 36 months	3	0.8

Table 4 – The maximum amount of time willing to wait to start orthodontic treatment

Majority (71.5%) of the patients were willing to wait for treatment for less than 3 months whereas 19.4% of patients were willing to wait for treatment for 4 – 6 months. Only 8.3% of patients were willing to wait for 6 – 12 months and 0.8% for more than 12 months.

Vast majority of the patients (88.7%) is used public transport to travel to the hospital while 9.1% used a private vehicle and 2.2% travelled by foot.

Eighty five percent (n = 318)) were able to afford travel expenses to make it to monthly appointments at the Orthodontic unit National hospital Kandy and 14.5% were unable to afford the travel expenses for regular visits to the clinic.

Eighty-eight percent (n = 328) of patients were accompanied by a guardian and 75.3% (n = 280n= ?) of patients or guardians had problems in getting time off work to visit the clinic for regular appointments.

Following initial screening at the clinic, 93.8% of patients was referred for necessary dental treatment done prior to commencing orthodontic treatment. Out of which 69.4% of patients were referred for scaling, 36% for restorations, 8.3% for extraction and 2.4% for prosthetic treatment.

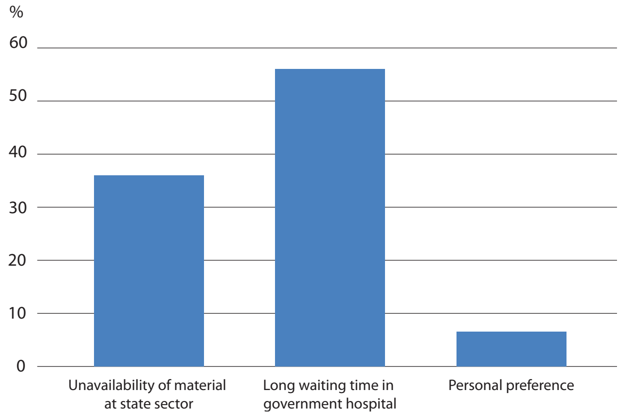

Figure 2 - The reason for seeking dental treatment in the private sector

Eighty-three percent (n = 296) opted to go to a government hospital in order to get these necessary dental treatments done while 15.6% (n = 58) had their treatment done in the private sector. Out of the patients that opted to go to the private sector, 55.93% of patients quoted long waiting time as the reason for not attending the government hospital for these dental treatments. Almost 37% (37.23%) had opted to go to the private sector due to unavailability of materials and 6.7% had done so due to their personal preference.

	Frequency (n)	Percentage (%)
Freely available	39	10.5
Short supply, clinic function normally	172	46.2
Short supply, clinic affected	161	43.3

Table 5 - Patients' impression on availability of materials and investigations in the hospital

Nearly 46% (n = 172) had an impression that drugs, dental materials and investigations were in short supply in the government hospital, but the clinics can function without disturbances and 43.3% of patients thought that drugs, dental materials and investigations were in short supply in government hospitals therefore the function of the clinics can be adversely affected. Minority of patients (10.5%) was under the impression that drugs, dental materials and investigations were freely available in government hospitals.

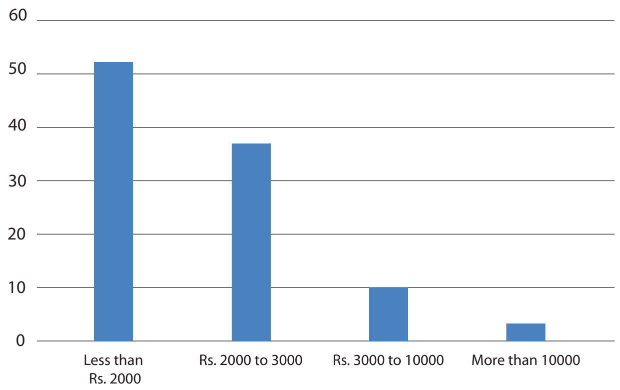

Figure 3 - Patients' thoughts on having to spend money to outsource materials or investigations

Almost 58% (n = 216) were willing to spend money on drugs, dental materials or investigations to be taken from the private sector, if they are unavailable currently at the National Hospital. However, 41.9% were not willing to spend money on drugs, dental materials or investigations if they are outsourced and were willing to postpone treatment until they are available at the National hospital.

Nearly 51% (n = 192)) of patients could afford spend less than Rs.2000 on drugs, dental materials or investigations if outsourced. Around 36.3% of patients were willing to spend Rs. 2000 – 5000, 10.2% were willing to spend Rs. 5000 – 10000 and 1.9% were willing to spend more than Rs.10000.

	Frequency (n)	Percentage (%)
Happy to spend	86	23.9
Happy to spend if absolutely necessary	226	60.8
Not happy to spend	57	15.3

Table 6 - Patients' thoughts on having to spend money to outsource materials or investigations

When asked about how they would feel about spending money on outsourcing drugs, dental materials or investigations, 60.8% were happy to spend money only if it is necessary and 15.3% were not happy about having to spend money on drugs, dental materials or investigations during treatment.

DISCUSSION

Orthodontic treatment plays a pivotal role in enhancing oral health, self-esteem, and overall quality of life. However, access to such specialized dental care is often influenced by socioeconomic factors. Amidst the economic crisis, many Sri Lankans have experienced a significant reduction in disposable income due to inflation, currency devaluation, and rising living costs. The economic downturn has also led to significant challenges in the healthcare sector as well, including reduced affordability of treatments, scarcity of resources (3, 4). The present study evaluates the unique intersection of healthcare delivery and patient experiences by assessing the patients' perceptions on undergoing orthodontic treatment amidst the economic crisis in Sri Lanka.

When considering the socio demographic characteristics of the patients awaiting orthodontic treatment at orthodontic unit NHK, majority of the patients were school going children between the age 10 – 19-years. In 54.3% of patients the monthly family income was less than Rs.50000 which is well below the average per capita income of Sri Lanka. Majority of the patients in the sample fall into the low – income category.

Improvement of oral function, aesthetics, and psychosocial well-being are the main outcomes of orthodontic treatment (7). As expected, 54.8% of patients in this cohort sought treatment due to concerns about their appearance. However, problems due to bullying, problems related to function and dental health were the other major causes for seeking orthodontic treatment in the remaining 45.2% of patients.

Majority of the patients were aware of the possible shortages in drugs, materials and investigations in the state sector due the financial crisis. Of the sample, 58.1% were willing to spend money on outsourcing materials and investigations. Sri Lanka imports 80% of its pharmaceuticals and practically all of its medical supplies, including equipment. The recent increase in Value Added Tax on health services from 12 to 15% has resulted in a surge in prices in materials and investigations. The maximum amount most of the patients willing to spend was less than Rs. 2000 on materials and investigations. However, the recent price hike of basic materials and investigations would be unaffordable by most patients.

It is widely accepted that orthodontic treatment lasts for a long time; an average treatment with fixed appliances approximately lasts 24.9 months (9). The patients are expected to make it to monthly or bimonthly appointments during course of their treatment. Regular, frequent visits to the clinic itself can be considered a financial burden when taking travel expenses and the cost of taking time off work into account. Large portion of patients in this cohort were accompanied by parents during their visits to the clinic and majority of them found it difficult to take time off work to attend the clinic at regular intervals.

Sri Lanka has a much-admired, publicly financed and free healthcare system. However, in light of the findings of this study we must reevaluate whether free health care is in fact "free". Drugs, materials and investigations which are in short supply due to the current economic crisis are being outsourced frequently as a solution for these shortages. As highlighted in the present study, this does not appear to be a solution feasible to all, as it increases the out of the pocket expenditure of patients and poses an additional burden to an already strained household income. In addition, patients in need of treatment and are unable to afford these materials and investigations, will be at a disadvantage. Furthermore, the clinicians have no control over the quality of the outsourced materials and investigations. Therefore, a sustainable solution in the long run is needed to navigate healthcare needs in the economic crisis.

The Sri Lankan government has limited resources to address the healthcare needs of its population during the economic crisis. Implementation of orthodontic treatment prioritization index for public sector orthodontic patients can be done to meet with the escalated demand for orthodontic treatment services amidst resource constraints(10). This ensures that the patients are prioritised depending on their need for treatment and scarce resources are allocated optimally.

However, this study was conducted at a single institution — the Orthodontic Unit of the National Hospital, Kandy — which may limit the generalizability of the findings to the wider Sri Lankan population particularly to patients seeking care in private healthcare settings. Patient responses were based on self-administered questionnaires and therefore subject to recall bias and social desirability bias, as participants may have under-reported or over-reported certain financial or attitudinal factors. The study also relied on self-reported family income levels without independent verification, which may have affected data accuracy. Future studies should aim to include a larger and more diverse sample by incorporating patients from multiple public and private orthodontic centers across different regions of Sri Lanka. This would allow for a more representative understanding of how varying socioeconomic and geographic factors influence perceptions and treatment decisions. Longitudinal research designs are recommended to assess how patient attitudes, financial capabilities, and treatment continuation evolve over time as the economic situation fluctuates.

CONCLUSION

Despite Sri Lanka's free public healthcare system, the findings reveal that "free" care often entails hidden costs for patients, particularly when materials, drugs, or investigations must be outsourced due to shortages. While a large proportion of patients were willing to contribute modest amounts toward these expenses, affordability remains a major barrier. Additionally, recurrent travel costs and difficulties obtaining leave from work further strain patients and their families throughout the lengthy course of orthodontic treatment.

These findings emphasize the urgent need for sustainable strategies to maintain equity in access to orthodontic care during periods of financial instability. Policy measures such as implementing a treatment prioritization mechanism, improving supply chain resilience, and offering targeted financial support for low-income patients could help optimize the allocation of limited resources.

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From Clinical Need to Healthcare Prioritization: A Review of Orthodontic Indexing and Contextualizing the Sri Lankan Index (OTPI)

Dr W.K.L. Perera

Consultant Orthodontist, District General Hospital, Matara

ABSTRACT:

Orthodontic indices standardize how we evaluate malocclusion, treatment complexity, clinical outcomes, and care priority. These objective metrics are vital in publicly funded healthcare systems, where specialist demand vastly outpaces capacity, making structured triage essential.

This review evaluates the conceptual frameworks, strengths, and limitations of major international instruments—including the Index of Orthodontic Treatment Need (IOTN), Peer Assessment Rating

(PAR), Index of Complexity, Outcome and Need (ICON), and the Index of Orthognathic Functional Treatment Need (IOFTN). A key focus is placed on the critical shift from measuring general treatment need to defining strict treatment priority within resource-constrained environments.

Finally, the discussion contextualizes these global tools alongside Sri Lanka's recently developed Orthodontic Treatment Prioritization Index (OTPI). As a locally tailored framework designed to optimize public-sector resource allocation, the OTPI highlights a broader global evolution: shifting from purely need-based assessments to service-prioritization models.

Key words : Orthodontics; Health Priorities; Malocclusion; Health Services Needs and Demand.

INTRODUCTION

Orthodontic treatment planning extends beyond clinical diagnosis. In modern healthcare systems, providers and policymakers must evaluate broader, systemic questions: Does the patient require intervention? How severe is the malocclusion, and how complex will the treatment be? Was the outcome successful? Crucially, within publicly funded services, how should patients be prioritized when resources are limited?

To standardize professional judgment, a variety of orthodontic indices have been developed. While originally designed to quantify malocclusion, their utility has expanded into epidemiology, clinical audits, specialist referral pathways, public funding eligibility, and service planning.

However, a universal index does not exist. Treatment need, complexity, outcome, and priority are distinct clinical and administrative constructs; an instrument that excels in one domain may fail in another [1,2,3,4].

This distinction is increasingly critical within publicly funded healthcare systems. In resource-constrained environments facing high clinical demand, orthodontic services cannot rely on chronological waitlists or unstructured clinical discretion. Instead, they require transparent, objective frameworks to determine which patients warrant expedited access to care. This challenge has driven growing interest in prioritization-oriented tools, leading to the development of the Orthodontic Care Index (OCI) and various country-specific prioritization systems . The present review critically examines the major orthodontic treatment need and prioritization indices and then situates the Sri Lankan Orthodontic Treatment Prioritization Index (OTPI) within this broader literature.

Conceptual framework of orthodontic indices

Orthodontic indices may be broadly grouped into four overlapping categories.

- Treatment Need Indices: These instruments evaluate whether a patient requires intervention based on clinical and, occasionally, aesthetic criteria. Primarily utilized for epidemiological screening and determining public funding eligibility, the Index of Orthodontic Treatment Need (IOTN) serves as the definitive archetype [1, 5].
- Outcome Indices: Designed to quantify the net clinical change achieved through intervention, these tools are central to clinical audits and quality assurance protocols. The Peer Assessment Rating (PAR) remains the classic benchmark [6,7].
- Complexity Indices: These indices estimate case difficulty to guide specialist referral pathways, project clinical workloads, and categorize patient cases. The Index of Complexity, Outcome and Need (ICON) explicitly integrates this dimension into its framework [3].
- Prioritization Indices: Operating within a narrower yet increasingly critical scope, these frameworks determine the optimal sequence of patient care in resource-limited environments. This category encompasses historical priority frameworks, specialized orthognathic tools like the Index of Orthognathic Functional Treatment Need (IOFTN), modern composite instruments like the Orthodontic Care Index (OCI), and locally tailored systems such as the Sri Lankan Orthodontic Treatment Prioritization Index (OTPI) [8,9].

A recurring challenge in orthodontic public health is the misapplication of treatment need indices as prioritization tools. Crucially, clinical need does not automatically dictate chronological urgency, nor does case complexity inherently imply priority. For example, a developing crossbite in a paediatric patient may demand more immediate intervention than a severe, yet time-insensitive malocclusion in an adult.

Recognizing this conceptual distinction has driven the contemporary shift toward prioritizationsensitive instruments.

Index of Orthodontic Treatment Need (IOTN)

The Index of Orthodontic Treatment Need remains one of the most influential orthodontic indices internationally. It was designed to assess the necessity for treatment, particularly in public health and service-allocation contexts [5].

Structure of the IOTN

The IOTN comprises two components:

1. Dental Health Component (DHC)
2. Aesthetic Component (AC)

The DHC classifies patients into five grades according to the severity of the most significant occlusal trait:

- Grade 1: no need
- Grade 2: little need
- Grade 3: borderline need
- Grade 4: great need
- Grade 5: very great need

The Index of Orthodontic Treatment Need (IOTN) assesses specific dental traits, including overjet, reverse overjet, crossbite, open bite, displacement, impeded eruption, hypodontia, and cleftrelated anomalies. Its Aesthetic Component (AC) utilizes a 10-point photographic scale to categorize increasing levels of dental unattractiveness. Strengths of the IOTN

The IOTN possesses several enduring strengths. It is a clinically familiar, relatively simple instrument widely implemented in both epidemiological research and healthcare delivery settings. By integrating both the Dental Health Component (DHC) and the Aesthetic Component (AC), the index effectively captures the dual clinical and psychosocial nature of orthodontic indications. Furthermore, it serves as an objective framework for establishing eligibility thresholds within publicly funded healthcare systems [10].

Limitations of the IOTN

Despite its widespread utility, the index exhibits distinct limitations:

- Scope of Classification: The IOTN is fundamentally a measure of treatment need rather than clinical priority. While it identifies candidates who qualify for intervention, it does not triage or sequence patients on a waiting list.
- Single-Trait Reliance: Its hierarchical scoring system relies on the single most severe trait, which risks oversimplifying the cumulative burden of complex, multi-trait malocclusions. it can fail to reflect cumulative malocclusion traits. Studies utilizing Item Response Theory (IRT) have explored which specific components have true discriminatory power.[11]
- Subjectivity: The aesthetic component remains inherently subjective and is highly susceptible to cultural variance and examiner calibration errors.
- Geographic and Ethnic Bias: The index may fail to adequately capture certain malocclusion traits of specific regional relevance, such as bimaxillary protrusion or distinct spacing patterns highly prevalent in South Asian populations [10].
- IOTN measures normative (dentally assessed) need, which frequently contradicts or fails to align with the patient's subjective psychosocial reality and oral health-related quality of life (OHRQoL). [12]

Relevance to Prioritization

Consequently, while the IOTN is a robust tool for validating whether orthodontic intervention is clinically justified, it is less effective as a standalone instrument for waiting-list prioritization within public health systems.

Peer Assessment Rating (PAR)

The Peer Assessment Rating index was developed to measure the degree of occlusal improvement achieved through orthodontic treatment [6].

Structure and purpose

PAR scores multiple occlusal relationships, including:

- anterior alignment,
- buccal occlusion,
- overjet, overbite,
- centerline discrepancy.

The pretreatment score is compared with the posttreatment score to quantify improvement. It is therefore an outcome measure, not a treatment-need instrument.

The Peer Assessment Rating (PAR) index is uniquely valuable for clinical audit and quality assurance protocols, providing an objective framework to compare treatment outcomes across varying clinicians, institutions, and therapeutic techniques. Consequently, it has become a benchmark instrument in specialist training programs and institutional service reviews [6].

Limitations of PAR

Conversely, the PAR index exhibits specific diagnostic limitations:

- Pre-Treatment Constraints: It does not determine initial treatment need, estimate case complexity, or establish patient priority.
- Narrow Diagnostic Focus: The index focuses primarily on static occlusal relationships, largely omitting broader psychosocial factors, skeletal discrepancies, or multidisciplinary treatment requirements. [13]

Due to these constraints, its utility in publicsector resource prioritization remains limited. Relevance to Prioritization

Ultimately, PAR is best conceptualized as a retrospective measure of treatment success rather than an anterior triage instrument.

The Index of Complexity, Outcome and Need (ICON)

To address the segmented nature of previous indices, the Index of Complexity, Outcome and Need (ICON) was developed. It successfully integrates treatment need, case complexity, and final therapeutic outcome into a unified, single-index scoring system [3].

Structure of ICON

ICON includes five weighted components:

- esthetic assessment,
- upper arch crowding or spacing,
- crossbite,
- incisor open bite or overbite,
- buccal segment anteroposterior relationship.

The individual items of the Index of Complexity, Outcome and Need (ICON) are scored and weighted mathematically to generate a composite value. This total score is then interpreted to determine initial treatment need, categorize case complexity, and evaluate final outcome acceptability.

Strengths of ICON

The primary advantage of the ICON lies in its comprehensive perspective, which surpasses the individual capabilities of the IOTN or PAR index. It is particularly valuable when clinicians require concurrent data on baseline treatment need, anticipated case difficulty, and projected therapeutic outcomes. Furthermore, because it was derived from an international expert consensus, the index carries high conceptual credibility across global orthodontic communities [1,3].

Limitations of ICON

However, the expanded scope of the ICON introduces distinct operational trade-offs:

- Increased Complexity: The index is inherently more intricate than its predecessors, making it less intuitive for rapid, routine clinical use. [14]
- Weighting Discrepancies: Its weighting structure may exhibit variable performance when applied across diverse or non-standardized populations. [15]
- Lack of Temporal Urgency: Like the IOTN, the ICON is not explicitly designed for waiting-list triage. While it successfully centralizes case complexity and clinical need, it fails to account for chronological urgency or optimal treatment timing [16].

Relevance to Prioritization

In summary, while the ICON represents a robust and sophisticated composite orthodontic index, it does not directly resolve the operational challenges of public-sector waiting-list triage.

Index of Orthognathic Functional Treatment Need (IOFTN)

The Index of Orthognathic Functional Treatment Need (IOFTN) was developed to standardize the clinical assessment of patients requiring orthognathic intervention within hospital settings [8].

Purpose and Scope

Distinct from generalized orthodontic indices, the IOFTN isolates the specific functional necessity of orthognathic correction. It is therefore uniquely applicable to severe skeletal discrepancies and dentofacial deformities that require combined surgical-orthodontic management.

Strengths of the IOFTN

The index provides a rigorous, structured framework for triaging patient access to orthognathic care, particularly within publicly funded healthcare systems. By recognizing that profound skeletal disharmonies cannot be effectively evaluated using standard orthodontic thresholds, the IOFTN serves as a crucial instrument for specialized hospital triage and clinical commissioning [8]. Limitations of the IOFTN

The primary limitation of the IOFTN is its highly specific clinical scope. It is restricted to a small subset of orthognathic candidates and cannot be utilized as a universal prioritization tool for routine dentoalveolar or minor skeletal malocclusions [17].

Relevance to Prioritization

The IOFTN represents a highly effective, condition-specific prioritization and need index. It demonstrates how traditional orthodontic assessment frameworks can be successfully adapted to manage high-resource, high-urgency subspecialty care.

Orthodontic Care Index (OCI)

As a recent development in orthodontic indexing, the Orthodontic Care Index (OCI) represents a major conceptual milestone by explicitly integrating clinical need, case complexity, and treatment priority within a single framework [9].

Conceptual Importance

The OCI acknowledges that resource allocation within real-world clinical services cannot be dictated by clinical need alone. A patient may present with a clear indication for treatment yet require less immediate intervention than another whose condition is more functionally compromising, urgent, or time-sensitive. Consequently, the OCI aligns more closely with the operational realities of public-sector orthodontics than traditional diagnostic indices.

Strengths of the OCI

- Explicit Prioritization: It incorporates treatment priority as a fundamental, core dimension rather than an secondary consideration.
- Systems-Level Integration: It effectively bridges objective clinical assessment with structural healthcare service allocation.

- Modern Healthcare Alignment: It conceptualizes orthodontic care delivery as a broader health-system management issue, rather than a strictly isolated diagnostic concern [9]. Limitations of the OCI

As a relatively contemporary instrument, the OCI has not yet achieved the widespread validation or extensive clinical adoption characteristic of the IOTN or PAR index. Furthermore, multi-dimensional composite systems inherently risk a higher administrative burden and reduced ease of use if the scoring protocols prove too elaborate for rapid, routine clinical settings [1,9]

Relevance to Prioritization

Among contemporary indices, the OCI serves as one of the most definitive examples of the paradigm shift toward integrated, publicservice-oriented orthodontic triage frameworks.

Historical Treatment Priority Index and other early systems

Early efforts to systematic patient triage include foundational treatment priority frameworks, such as the orthodontic Treatment Priority Index (TPI) and early Scandinavian public dental service priority models [18,19].

Historical Contribution

These pioneering systems established the critical principle that malocclusion severity and subsequent treatment access could be objectively systematized. In doing so, they provided the essential intellectual and methodological foundations for contemporary orthodontic indices.

Limitations

From a modern perspective, these historical systems are limited by outdated scoring paradigms and a relatively narrow conceptualization of orthodontic need. Specifically, they offer insufficient consideration of contemporary psychosocial, patient-centered, and multidisciplinary diagnostic dimensions.

Relevance to Prioritization

Although largely superseded by sophisticated modern instruments, these early frameworks remain vital for tracing the paradigm shift and conceptual evolution of resource prioritization within public orthodontics.

Interceptive referral indices and related contemporary tools

Recent academic work has focused on developing indices tailored for interceptive orthodontic referrals, particularly in pediatric populations [20, 21]. These specialized instruments operate on the clinical premise that chronological timing can be the primary determinant of treatment priority. For instance, a moderate malocclusion in the mixed dentition may necessitate more urgent intervention than a morphologically more severe, yet stable, discrepancy in late adolescence.

Strengths of Interceptive Indices

- Growth-Dependent Utility: They exhibit high relevance for growthdependent therapeutic interventions.
- Streamlined Triaging: They provide structured frameworks that optimize primary-to-secondary care referral pathways.
- Preventive Alignment: They align closely with modern, proactive healthcare models centered on prevention and early interceptive care.

Limitations of Interceptive Indices

- Restricted Demographic Scope: They possess a narrow age applicability, limiting their utility outside of pediatric cohorts [20]
- Incomplete Diagnostic Spectrum:

They are not designed to address fullspectrum orthodontic triage or complex, adult malocclusions.

Relevance to Prioritization

Within public orthodontics, these instruments are highly significant because they foreground a critical clinical principle: treatment urgency can be temporal and developmental rather than purely morphological.

Comparative overview of major indices

An overview of the strengths and major limitations of the commonly used indices are provided in Table 1.

Index	Primary purpose	Major strengths	Major limitations
IOTN	Assess treatment need	Simple, widely used, combines health and aesthetics	Not a true prioritization index
PAR	Assess treatment outcome	Strong for audit and treatment assessment	Does not assess need or urgency
ICON	Assess need, complexity, outcome	Broad and integrated	More complex; not specifically priority focused
IOFTN	Assess orthognathic functional need	Highly useful for severe skeletal triage	Limited to orthognathic cases
OCI	Assess need complexity priority	Explicitly service-oriented and priority-sensitive	Newer and less widely validated
Historical TPI / Swedish models	Severity estimation	Historically importance	Less aligend with modern concepts
Interruptive referral indices	Early referral timing	Strong for child and growth-related triage	Narrow scope

Methodological and Conceptual Variance across Orthodontic Indices

A synthesis of the orthodontic index literature reveals several recurring methodological and conceptual challenges.

Clinical Need Versus Resource Prioritization

A primary thematic conflict is that clinical treatment need does not inherently equate to treatment priority. While indices like the IOTN are highly valuable for validating whether an intervention is clinically justified, they lack the diagnostic nuance required to sequence patient access within resourceconstrained public healthcare systems [1,9].

Case Complexity Versus Chronological Urgency

Clinical complexity must also be dissociated from developmental urgency. A highly complex skeletal or dental malocclusion may remain stable and non-time-sensitive. Conversely, a less complex interceptive case may demand urgent intervention within a narrow, growth-dependent physiological window [1, 9].

Evaluation of Aesthetic and Psychosocial Factors

While aesthetic and psychosocial dimensions are increasingly recognized as vital components of patient-centered care, they remain imperfectly quantified. Integrating aesthetic components enhances patientcenteredness, but it simultaneously introduces substantial subjectivity and variability into the assessment framework[9].

Population Specificity and Geographic Bias

Malocclusion traits and phenotypic distributions vary significantly across global populations. Consequently, indices originally developed in Europe or North America frequently fail to adequately capture morphologic patterns of unique regional relevance, such as those prevalent in South Asian populations [22].

Requirements for Examiner Calibration

The diagnostic validity of most orthodontic indices depends heavily on rigorous examiner calibration. Inter-examiner and intra-examiner reliability can deteriorate significantly in the absence of continuous, standardized training protocols [6,14,23].

Contextualization within the Sri Lankan Healthcare Framework

The development of the Sri Lankan Orthodontic Treatment Prioritization Index (OTPI) represents a direct strategic response to these documented limitations. It addresses the gaps left by traditional indices when applied to a highly resource-constrained, public-sector healthcare delivery system [24].

The OTPI is presented as a 22-item composite index comprising four broad domains:

- Special criteria (5 items)
- Skeletal component (5 items)
- Soft tissue component (2 items)
- Dento-alveolar component (10 items)

The design is straightforward. Special criteria confer the highest priority automatically. In the absence of special criteria, severity is graded across the other domains into high, moderate, and low categories, scored as 5, 3, and 1, respectively. Final prioritization is determined by the highest score in any dimension.

The special criteria are perhaps the most clinically and ethically significant part of the instrument. They include:

- Cleft lip and palate, facial syndromes, or dentofacial deformities requiring multidisciplinary management;
- Growing patients needing interceptive orthodontics;
- Cases referred for major psychosocial, quality-of-life, or sleep-related concerns;
- Adjunctive orthodontics for prosthetic or periodontal treatment;
- Impacted teeth other than third molars.

This structure reflects real-world orthodontic triage logic. It privileges cases where delay may worsen prognosis, increase complexity, narrow treatment windows, or adversely affect broader health and function.

The authors of the Orthodontic Treatment Priority Index (OTPI) study demonstrate that conventional indices—such as the Index of Orthodontic Treatment Need (IOTN), Peer Assessment Rating (PAR), and Index of Complexity, Outcome and Need (ICON)—fail to address the primary operational challenge faced by consultant orthodontists in Sri Lanka: allocating limited publicly funded resources amid overwhelming demand.

Novel Contributions and Structural Adaptations of the OTPI

The OTPI advances the existing literature by localizing and operationalizing patient prioritization specifically for Sri Lanka's public healthcare infrastructure. It diverges from traditional clinical indices through four distinct mechanisms:

1. Dedicated Triaging Focus

Unlike the IOTN or ICON, which primarily assess eligibility for care, the OTPI is engineered specifically to determine treatment chronological urgency, optimizing resource allocation.

2. Integration of High-Priority Clinical Subsets

The OTPI prioritizes complex clinical presentations that heavily impact public health outcomes. Highest priority is assigned to:

Cleft lip and palate and craniofacial syndromes.

Multidisciplinary dentofacial deformities.

Interceptive needs in growing patients.

Adjunctive orthodontic requirements and impacted teeth.

Severe psychosocial or oral-health-related quality-of-life (OHRQoL) impairments.

3. Population-Specific Morphological Adaptation

Traditional indices often underrepresent specific dentofacial traits prevalent in South Asian demographics. The OTPI corrects this by incorporating bimaxillary proclination and spacing [24], adhering to the epidemiological principle that orthodontic indices must align with population-specific phenotypes.

4. Public Sector Resource Management

Rather than functioning solely as a clinical metric, the OTPI operates as a public health management tool. This positions it alongside modern priority-driven frameworks like the OCI, while directly addressing the unique capacity and service constraints of the Sri Lankan healthcare system.

Alignment of the OTPI with Contemporary Global Trends

The development of the Orthodontic Treatment Priority Index (OTPI) aligns with a paradigm shift in orthodontic indexing, moving from purely severity-based measurements toward frameworks that integrate healthcare access, clinical urgency, and health service planning. Conceptually, the OTPI succeeds an established lineage of international triaging systems, which includes:

- Historical treatment priority models,
- Scandinavian public health prioritization frameworks,
- The Index of Orthognathic Functional Treatment Need (IOFTN) for functional triaging,
- Interceptive referral indices designed for pediatric populations,
- The Orthodontic Components of Index (OCI) as an integrated resource allocation framework

Consequently, the OTPI is not an isolated development; rather, it represents a population-specific contribution to a broader global challenge: optimizing the equitable allocation of orthodontic care under systemic resource constraints.

Critical Evaluation and Methodological Challenges

While the OTPI represents a significant advancement for the Sri Lankan public healthcare sector, it shares the intrinsic methodological challenges common to contemporary prioritization tools. Like the OCI and related modern frameworks, the OTPI must continuously balance clinical realism, objectivity, administrative simplicity, and inter-examiner reproducibility.

Although initial validation metrics are promising, extensive multicenter longitudinal testing is required to confirm its clinical maturity and diagnostic robustness.

Nevertheless, the OTPI successfully addresses a critical operational void in Sri Lanka's public orthodontic infrastructure—a systemic gap that traditional indices such as the IOTN, PAR, and ICON fail to resolve.

DISCUSSION

The evolution of orthodontic indexing mirrors the shifting paradigms of orthodontic care. Historical frameworks primarily quantified the severity of malocclusion to satisfy epidemiological or educational objectives. Subsequent generations of indices expanded their diagnostic scope to evaluate clinical treatment need, complexity, and posttreatment outcomes. More recently, however, contemporary healthcare research acknowledges that within publicly funded systems, the critical challenge is not merely identifying treatment eligibility, but rather sequencing and justifying care allocation under resource constraints.

Within this framework, traditional indices retain distinct clinical utility but exhibit defined operational boundaries:

- The IOTN remains a robust instrument for screening and initial need assessment.
- The PAR index continues to serve as a standard for post-treatment outcome auditing.
- The ICON offers a comprehensive composite measure of need, complexity, and outcome.
- The IOFTN is an indispensable tool for specialized orthognathic triaging.
- The OCI and other emerging frameworks represent the next iteration of indexing by directly integrating health service prioritization into clinical metrics.

The Sri Lankan Orthodontic Treatment Priority Index (OTPI) aligns with this modern trajectory. It directly addresses the pragmatic realities of an overburdened public orthodontic infrastructure, acknowledging that equitable healthcare access requires a more sophisticated mechanism than a strictly chronological waitlist. Ultimately, the significance of the OTPI lies in its capacity to translate global conceptual advancements into a locally operationalized, context-specific framework.

CONCLUSION

Orthodontic indices are indispensable instruments for standardizing clinical assessment, therapeutic planning, resource allocation, and outcome auditing. However, these systems are not interchangeable; each possesses distinct operational parameters. The IOTN serves primarily as a metric for treatment need; the PAR index functions as an outcome auditor; the ICON operates as a composite framework evaluating need, complexity, and outcome; the IOFTN provides specialized functional triaging for orthognathic care; and the OCI introduces an integrated approach that incorporates treatment priority. Collectively, these frameworks, alongside historical and interceptive indices, illustrate the conceptual evolution of prioritization strategies within the discipline.

The Sri Lankan OTPI study represents a vital, context-specific advancement within this global landscape, directly addressing the operational gap between identifying clinical need and allocating healthcare resources. By focusing explicitly on public-sector prioritization, incorporating populationspecific malocclusion phenotypes, and recognizing the critical role of interceptive, psychosocial, and multidisciplinary indicators, the OTPI extends the indexing literature into an area of increasing international significance.

Ultimately, its most profound contribution is conceptual: it reinforces that within modern, publicly funded orthodontic systems, the definitive administrative challenge is no longer merely determining who qualifies for treatment, but establishing who should be treated first, and on what clinical grounds.

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Retention and Stability Following Active Orthodontic Treatment: A Review of Current Evidence

VSN Vithanaarachchi

Professor in Orthodontics, Division of Orthodontics, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka.

ABSTRACT:

Retention is the phase of orthodontic treatment aimed at maintaining teeth in their corrected positions after active appliance removal. Without retention, relapse is the tendency for teeth to return toward pretreatment positions occurs in up to 90% of cases within 10–20 years. This review critically evaluates the biological basis of relapse, compares fixed and removable retention protocols, examines failure rates and periodontal implications, and synthesizes evidence on long-term stability from 2020–2025. Fixed stainless-steel retainers remain the gold standard for maintaining mandibular anterior alignment, while vacuum-formed retainers are associated with superior periodontal health but depend heavily on compliance. Meta-analyses indicate no significant difference in relapse between extraction and non-extraction treatment when adequate retention is used. Current consensus favors indefinite or lifelong retention, particularly for lower incisors, with shared responsibility between orthodontist, patient, and general dentist. However, Cochrane reviews highlight that evidence quality remains low, and no single protocol guarantees absolute stability. This paper provides evidence-based recommendations for retention planning, material selection, monitoring, and management of complications.

Key words : Orthodontic retention, relapse, stability, fixed retainer, vacuum-formed retainer, compliance, periodontal health, Cochrane review

INTRODUCTION

Orthodontic treatment is not complete at debonding or active orthodontic phase. The final positions of teeth represent a balance between skeletal, dental, and soft tissue forces that may be inherently unstable. Retention is defined as maintaining optimal aesthetic and functional tooth positions following cessation of active orthodontic tooth movement.[2]

The necessity for retention demands from three primary biological processes: 1) Reorganization of periodontal and gingival fibers, 2) Unfavorable growth continuing after treatment, and 3) Age-related physiological changes in the dentition.[3][6]

Little et al.'s seminal longitudinal studies demonstrated that only 10% of mandibular anterior alignment remained stable 10–20 years post-retention, with 70% showing moderate to severe relapse. These findings established retention as an integral phase rather than an adjunct.[21]

The 2023 Cochrane Review on retention procedures concluded that despite hundreds of studies, there is insufficient high-quality evidence to firmly recommend one retainer or protocol over another. Most trials have short follow-ups <2 years, inadequate sample sizes, and high risk of bias. This review therefore aims to:

1. Summarize the etiology of relapse using current biological and clinical data
2. Compare efficacy, failure rates, and periodontal effects of fixed vs removable retainers
3. Evaluate the impact of treatment factors like extractions, duration, and compliance
4. Discuss adjunctive procedures and emerging technologies
5. Provide clinical guidelines based on 2020–2025 evidence [2]

BIOLOGICAL AND MECHANICAL BASIS OF RELAPSE:

1. Periodontal and Supracrestal Fiber Remodeling:

Tooth movement stretches collagenous principal fibers of the periodontal ligament and gingival supracrestal fibers. While PDL fibers reorganize within 3–4 months, elastic supracrestal fibers require 8–12 months and may never fully adapt to new positions. This differential remodeling explains early relapse tendency.[3][6]

Franzen et al. demonstrated in rats that orthodontic relapse is associated with significant osteoclast activity and alveolar bone remodeling, not merely fiber recoil. This suggests retention should stabilize teeth until bone maturation completes.[11]

2. *Neuromuscular Equilibrium:*

The dentition exists in a "neutral zone" balanced by tongue, lip, and cheek pressures. Orthodontic treatment that positions teeth outside this zone is prone to relapse. Periodontally Accelerated Osteogenic Orthodontics (PAOO) increases vestibular bone thickness by 0.32 mm and reduces gingival recession by 3.12 mm, potentially expanding the neutral zone and improving stability.[6][12]

3. Growth and Aging:

Post-treatment growth, particularly late mandibular growth, can alter occlusal relationships. Gender-specific maturational changes occur: PAR score changes in males 12–22 years and females 19–39 years. Beyond 5 years post-debond, most dental changes are attributed to physiological aging rather than treatment relapse. These include continued eruption, mesial drift, and interproximal attrition causing lower incisor crowding.[19][13][18]

4. Tooth-Level Factors:

Rotated teeth are highly unstable due to elastic fiber arrangement. Teeth moved significantly from original positions, especially across cortical plates, have higher relapse potential. Extraction sites show variable stability; however, systematic reviews find no difference in overjet, overbite, or irregularity relapse between extraction and non-extraction cases when proper retention is used.[6][18][9]

FACTORS INFLUENCING POST-TREATMENT STABILITY:

1. Patient-Related Factors:

Factor	Odds Ratio for relapse	Evidence level
Poor retainer compliance	3.5	Pediatric cohort, p=0.002
Severe initial malocclusion	2.8	Pediatric cohort, p=0.004
Growth changes	2.2	Pediatric cohort, p=0.022
Age at debond	Younger = higher risk	Systematic review
Periodontal health	Compromised = higher risk	Consensus

Mandibular crowding relapses in 35% of pediatric patients at 3-year follow-up, making it the most unstable correction. Meanwhile, Maxillary crowding relapses in 30%.[10][20]

2. Treatment-Related Factors:

1. Extraction vs Non-extraction: Meta-analysis of 10 studies, 720 patients, found no statistically significant differences in relapse of overjet SMD 0.52, overbite SMD 0.41, or Little's Irregularity Index SMD 0.71. Clinical considerations should drive extraction decisions, not stability concerns.
2. Treatment duration: No direct correlation, but prolonged treatment may increase root resorption risk, indirectly affecting stability.
3. Finishing quality: Achieving proper interdigitation, root parallelism, and incisor torque improves stability.[9][6][18]

3. Retention-Related Factors:

1. Type of retainer: Fixed retainers superior for lower 3-3 alignment at 4 years. However, VFRs depend on compliance.
2. Duration: Retention <6 months associated with high failure. Indefinite retention now recommended for mandibular anteriors.
3. Bonding protocol: Use of bonding resin reduces failure rate of fixed retainers.[5][1][2][8]

RETENTION PROTOCOLS: DESIGN, MATERIALS, AND EFFICACY

1. Fixed Retainers:

Bonded lingual retainers are the most prescribed retention for mandibular anteriors in Europe. Materials include multistranded stainless steel, plain stainless steel, titanium molybdenum alloy, and glass-fiber reinforced composite.[3]

Efficacy: Network meta-analyses rank digitally fabricated and multistranded stainless-steel retainers as most effective for preserving inter-canine width and anterior alignment. CAD/CAM fabricated retainers showed less change in inter-canine distance: -0.03 mm vs +0.12 mm for conventional at 2 years.[7][14]

Failure rates: Systematic review reports 7.3% to 50% failure rate and most failures occur in first 3–6 months. Debonding at wire-composite interface is most common with spiral wires and wire fracture more common with fiber splints. TMA wires have lower debonding rates than stainless steel wires.[6]

Complications:

1. Unwanted tooth movement: 30–40% bonding failure rate can result in active retainers causing torque or tipping.
2. Periodontal effects: Fixed retainers restrict oral hygiene, increasing plaque, calculus, and gingival inflammation. However, stainless steel retainers show statistically insignificant effects on periodontal health vs no retainer when hygiene is maintained. Glass-fiber reinforced retainers show worse periodontal complications and should be discouraged.
3. Caries risk: Increased but manageable with hygiene instruction.[6][4]

2. Removable Retainers:

Vacuum-formed retainers (VFRs) and Hawley retainers are most common. VFRs are preferred for aesthetics and cost.[7]

Efficacy: 4-year RCT found VFRs less effective than fixed for mandibular anterior stability: median 1.64 mm more irregularity. However, no difference in inter-canine width, intermolar width, arch length, or extraction space opening.[5]

Periodontal health: VFRs associated with less plaque, calculus, and gingival inflammation vs fixed retainers and patients find them easier to clean.[4]

Compliance: Compliance is the major limitation and effectiveness directly linked to wear time. Near 24-hour wear needed for first 6 months, then nightly. Poor compliance increases relapse but patient dropout from studies may underestimate non-compliance rates.[10][7]

Breakage: Common due to bruxism or improper handling. 3D-printed retainers are emerging but 1-year RCTs show no superiority over thermoformed VFRs yet.[15]

3. Dual Retention:

Simultaneous fixed and removable retention is favored by 58–66% of European orthodontists. The Common protocol is lower bonded retainer from canine to canine and upper VFR. This combines the stability of fixed for relapse-prone lower incisors with removable coverage for posterior segments. At 24 months, dual retention maintains arch stability effectively.[17]

LONG - TERM OUTCOMES: STABILITY, SURVIVAL, AND PATIENT FACTORS

1. Stability Beyond 2 Years:

Relapse continues up to at least 5 years post-debond period. A 2-year RCT comparing VFR and bonded retainers found both groups showed relapse, but fixed retainers maintained better lower anterior alignment. After 5 years, changes are considered physiological aging.[19][16]

2. Retainer Survival:

Fixed retainer survival rate is 71.1% at 3 years before debonding/ fracture. Despite failures, patients report no negative impact on oral health-related quality of life. Indirect bonding reduces chairside time but not failure rate if protocol is followed.[7][3]

3. Patient Satisfaction and Oral Health Related Quality Of Life (OHRQoL):

Fixed upper retainers negatively associated with OHRQoL short-term vs no upper retainer. However, dissatisfaction with treatment outcome is only slightly associated with objective stability measures. This highlights the importance of patient-centered outcomes in retention planning.[7]

4. Periodontal Health Long-Term:

4-year follow-up RCT found no statistical difference in periodontal outcomes between fixed and VFR groups, though gingival inflammation and plaque were common in both. This contradicts earlier beliefs that fixed retainers always worsen periodontal health, emphasizing the role of hygiene instruction.[5][4]

ADJUNCTIVE PROCEDURES TO ENHANACE STABILITY:

1. Interproximal Reduction (IPR):

Creating broader contact points may reduce rotational relapse. However, the evidence is limited and Cochrane 2023 found insufficient data to recommend routine IPR for retention.[2]

2. Circumferential Supra-crestal Fiberotomy (Pericision):

Surgical cutting of supra-crestal fibers to reduce rotational relapse and effective according to short-term studies but invasive and not widely adopted.[2]

3. Overcorrection:

Positioning teeth slightly beyond ideal to compensate for expected relapse indicate commonly for rotations and Class II correction but should be balanced against occlusal interference risk.[18]

4. Periodontally Accelerated Orthodontics:

Combines corticotomy with grafting increases bone thickness and reduces recession, potentially improving long-term stability. [12]

RETENTION DURATION:

Historical protocols of 1–2 years are obsolete. Current evidence shows:

1. First 6 months: Highest relapse risk; near full-time wear for removable retainers critical
2. 1–2 years: Continued remodeling; nightly wear minimum
3. Beyond 2 years: Stability improves but not guaranteed
4. Indefinite/Lifelong: Recommended for mandibular anteriors and patients with severe initial crowding [1][13][2]

The 2026 AJO-DO article states “retention is a long-term lifestyle choice” and responsibility is shared between orthodontist, patient, and dentist. should monitor retainers at routine hygiene visits.[1]

CLINICAL GUIDELINES AND DECISION-MAKING (2023-2025 CONSENSUS)

1. Planning Retention:

Use shared decision-making and need to discuss following aspects with a patient [1][16].

1. Risk of relapse without retention
2. Pros/cons of fixed vs removable
3. Lifelong commitment implications
4. Cost of replacement and repairs

2. Material and Design Recommendations:

1. Mandibular anterior: Multistranded SS bonded 3-3, bonded to each tooth, using bonding resin. CAD/CAM an option if available.
2. Maxillary arch: VFR if stability adequate, or fixed 2-2 if spacing was present. Avoid fixed retainers if deep bite risks debonding.
3. Avoid: Glass-fiber reinforced retainers due to periodontal complications.
4. Dual retention: Lower fixed and upper VFR for most comprehensive cases.[14][3][8][4][17]

3. Monitoring Protocol:

1. 0–6 months: Check monthly for fixed retainer integrity and VFR fit
2. 6–24 months: Every 3–6 months
3. >24 months: Annual checks, transition to general dentist
4. At each visit: Assess for wire activation, debonding, hygiene, patient concerns [6][16][1]

4. Managing Failures:

Deboned fixed retainer should be rebounded within 1–2 weeks if possible. If repeated failure of fixed retainers, consider of VFR. With Lost or broken VFR, replace is needed immediately as teeth can relapse within days. If any unwanted tooth movement is evident, remove fixed retainer and realign if needed and new retention plan should be indicated.[6][10][1]

EMERGING TECHNOLOGIES AND FUTURE RESEARCH

Early RCTs show 3D printed retainers similar fit to thermoformed but no long-term stability data yet. Shape-memory and robotic bent wires of CAD/CAM retainers may reduce failure by improving passive fit. Researches are more concerned of bioactive retainers with fluoride-releasing or antimicrobial composites to mitigate caries and periodontal risk. Use of artificial intelligence (AI) in retention planning may facilitate the prepare of predictive models for individual relapse risk based on pre-treatment records. However, high-quality research trials are needed with more than 2-year follow-up assessing stability, retainer survival, periodontal health, patient satisfaction, and cost-effectiveness.[15][14][8][2]

CONCLISION:

Absolute stability following active orthodontic treatment is biologically unattainable, but appropriate retention minimizes clinically significant relapse. [1][2] However, no single retainer is universally superior and choice must be individualized. Fixed stainless-steel retainers are most effective for mandibular anterior alignment but require monitoring for failure and hygiene. VFRs offer better periodontal health but depend on compliance of patients but they are less effective for lower incisor stability in long-term. Dual retention balances efficacy and safety is important for most patients. Indefinite retention should be the default, especially for lower 3-3, with clear transfer of responsibility to patient and general dentist. Further, extraction choice does not affect relapse when adequate retention is provided.[4][6][5][10][17][1][9]

The orthodontist's role extends beyond debonding to educating patients that retention is a lifelong commitment. Future research must prioritize patient-centered outcomes and long-term data to refine evidence-based protocols.[1][2]

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Patient and parent motivation towards orthodontic treatment among patients attending orthodontic clinic, Teaching Hospital, Karapitiya, SriLanka.

Ranasinghe H.A.S.S[1], Pathirage S.L

[1]Senior Registrar in Orthodontics, National Hospital, Galle, Sri Lanka

[2]Consultant Orthodontist, National Hospital, Galle, Sri Lanka

ABSTRACT:

Objective: The main purpose of the study was to assess the level of patient and parent motivation towards orthodontic treatment and to determine the main reasons for seeking orthodontic treatment. The association between socio-demographic factors, clinical parameters and the motivation levels of both patients and parents were also assessed.

Materials and methods: A descriptive cross sectional study was conducted among new patients attending orthodontic clinic and systematic sampling method used to select the study sample. Self administered questionnaires were given to both patients and parents. Clinical parameters were obtained using a clinical information sheet for each selected patient. Data analysis was performed using SPSS 21 and chi square test and Pearson's correlation test were used.

Results: There were statistically significant relationships between level of motivation of the patient and the severity of the malocclusion(X^2=9.310, p=0.025) , the reason for seeking treatment by the patient(X^2=31.422, p=0.000) and the parent.(X^2=20.427 , p=0.000). Furthermore there were statistically significant relationships between level of motivation of the parent and the severity of malocclusion of the patient (X^2=17.503 , p=0.001) ,the reason for seeking treatment by parents(X^2=6.818 , p=0.033). There was a statistically significant association and positive high correlation between the level of motivation of the patient and the level of motivation of the parent.(p=0.000, Pearson correlation r value 0.804)

Conclusions: The motivation levels of patients and parents are closely associated and vary significantly depending on the reason for seeking treatment by patient and parent and the severity of the malocclusion of the patient.

Key words: level of motivation, orthodontic treatment

INTRODUCTION

A person's quality of life may be affected by the presence of a malocclusion and this may be the reason why there is such a high demand for orthodontic treatment. Despite the demand, it is of utmost importance to obtain a satisfactory treatment outcome. There are several contributory factors whereas the patient's and their parent's motivation is one of the important ones. Determining the patient's and their parent's motivation in seeking orthodontic treatment prior to beginning of the treatment is of utmost importance. It will help obtain a satisfactory treatment outcome for both the clinician and the patient.

Motivation for seeking treatment can be classified as external motivation and internal motivation.[1] External motivation is brought on by the pressure from another individual whereas internal motivation comes from within the individual, based on his or her own assessment of the situation and desire for treatment. It is noted that the value of understanding the patient's motivation for orthodontic treatment and that there is a difference between motivations and expectations, hence considering them during early clinical visits is much needed.[2] Studies showed that by assessing the motivation prior to starting treatment gives the possibility to understand mutually agreed objectives and to identify the patients with unrealistic goals.[3]

Evidence showed that attractiveness and increasing self confidence have been the major motivating factors behind orthodontic treatment.[4] Age, gender, severity of malocclusion, education level , self perception of facial appearance, influence of the parents, referral by the dental surgeon, influence of relatives, friends are some other motivating factors linked to orthodontic treatment.[5]

Motivation of the patient and parent towards orthodontic treatment should be assessed by the orthodontist at the initial clinical visits. This will help understand the desires of the patient and parent and to assess their level of treatment cooperation. To obtain a successful orthodontic treatment outcome, patient cooperation is essential.

In orthodontic treatment, patient and parent cooperation is vital to keep regular appointments, for high compliance in wearing removable appliances, head gears and rubber bands, for maintenance of oral hygiene and to refrain from chewing hard stuff.[6] Studies have demonstrated that the lack of motivation lead to lack of cooperation and discontinuation of treatment.[7] According to literature, there is a positive correlation between lack of cooperation and time length of the appliance wear.[8] A study have concluded that patients' level of motivation is one of the major determinants in cooperation with their orthodontists' treatment recommendation.[9] Furthermore, it has noticed that if the parents' awareness of their children's treatment is lacking, parental support and encouragement perceived by the patient is also reduced. Lack of treatment cooperation leads to compromised treatment, slow progression of treatment, loss of chair side time and frustration.[6] So assessing the treatment motivation of the patient and parent is crucial in anticipating their level of future treatment cooperation and possibility of achieving expected treatment outcome.

Expectations of the patient and parent from orthodontic treatment differs. Evidence suggests that expectations should be identified prior to commencement of treatment and patients' objectives should be included in the treatment goals.[2] One study has pointed out that patients in that study have identified three main benefits of orthodontic treatment including health related behavioral changes, dental health and psychosocial influences. This is important to both the patient and the orthodontist in making treatment goals and during obtaining informed consent.[10]

Motivating factors and their relative importance could change between communities. For example, a study revealed that main motivating factor for seeking orthodontic treatment by adolescent American students was to improve their facial appearance whereas Japanese and Chinese students were more focused on specific behaviors in others.[11] Evidence showed that attitudes towards orthodontic treatment in Asian community were different compared to those reported in Caucasians.[12] Therefore, we need to look at the factors to identify the importance of them in our context. This would help the clinicians to focus and identify the most relevant facts for the given age and gender category. This would make things easy as they will not have to focus on the whole list. So the orthodontist will be able to provide an efficient treatment and obtain a mutually satisfying outcome.

In this study, we intend to assess the level of motivation of the patients and parents and to find out the main reasons for seeking orthodontic treatment. Furthermore we hope to assess the association between age, gender, ethnicity, educational level , socioeconomic level of the patient and parent, type and severity of malocclusion and the level of motivation towards orthodontic treatment.

MATERIALS AND METHODS

Descriptive cross-sectional study was conducted at orthodontic clinic, Teaching hospital, Karapitiya from March 2024 to March 2025. All the new patients attending to the orthodontic clinic , Teaching Hospital Karapitiya during the period of the study with the following inclusion and exclusion criteria were selected to the study sample. Patients could refrain from participating or can withdraw at any time.

Patients attending to orthodontic clinic, Teaching Hospital,Karapitiya; 10 years old and above were included in to the study sample. Parents of included study participants were also incorporated into the study. Patients with history of previous orthodontic treatment,Mentally subnormal patients and patients with cleft lip, palate and related syndromes were excluded.

Systematic sampling technique was used to select the study sample. First patient was selected randomly and from that patient onwards every other patient in the clinic registry who fulfills the inclusion and exclusion criteria was selected. This method was used each day until the sample size achieved.

The formula for calculating a population proportion with absolute precision was used to calculate the sample size" (Lwanga & Lemeshaw, 1991) and sample size was 422.

Self administered questionnaire with close ended questions was used. Questionnaire included demographic data, main reasons for seeking orthodontic treatment and assessment of level of motivation. Clinical information regarding type and severity of malocclusion were also obtained. Statements of the questionnaire which were used to assess the level of patient and parent motivation were obtained from the study on ADOLESCENT PATIENT'S TREATMENT MOTIVATION AND SATISFACTION WITH ORTHODONTIC TREATMENT by Lauren.E.Anderson, Airton Arruda and Marita Rohr Inglehart published in Angle Orthodontist, vol 79, No 5,2009 , and adopted to our study accordingly. Likertt scale was used to score the responses.

Questionnaire was pre-tested with 20 patients prior to the study. Relevant changes on wording and phrasing were done accordingly to maximize the understanding. Questionnaire was produced for expert opinion to obtain judgmental validity. Questionnaire made in English was translated to both Sinhala and Tamil languages. It was done meaningfully, under the guidance of the supervisor, using appropriate wording while preserving the cultural sensitivity. Then the questionnaires were translated back into English by two independent persons, in order to ensure the validity and reliability. The translated version of questionnaires were again submitted to an expert panel and approval was granted.

Data were collected during the new patients' clinic. Two dental surgeons were collecting data in the clinic. Self administered questionnaire was given to both the patient and the parent. Oral examination for assessing the type of malocclusion and IOTN (severity of malocclusion) was carried out by the principal Investigator.

The data obtained were entered and analyzed using statistical package for social sciences (SPSS.21) by the Principal investigator. Demographic data, type and severity of malocclusion and main reasons for seeking orthodontic treatment presented as percentages. In the assessment of level of motivation, responses are weighted according to the importance of relevant question regarding level of motivation. Minimum scores were 12 and 11 and maximum were 60 and 55 in relation to patient and parent respectively. The level of motivation was categorized into 3 groups based on the score of Likertt scale. Relationships between the level of motivation and variables were assessed using chi-square analysis and Pearson correlation test.

RESULTS

Table 1 - Socio-Demographic Characteristics (n=422)

Variable	Characteristic	Number	%
Age	10 -14 Years	167	39.6
	15 -19 Years	189	44.8
	20 -24 Years	49	11.6
	25-29 Years	16	3.8
	>30 Years	1	0.2
Gender	Male	146	34.6
	Female	276	65.4
Nationality	Sinhala	380	90.0
	Sri Lankan Moore	31	7.3
	Tamil	11	2.6
Income	Rs. = <25,000	103	24.4
	Rs. 25,001 - 50,000	219	51.9
	Rs. 50,001 - 75,000	61	14.5
	Rs. 75,001 - 100,000	23	5.5
	Rs. > 100,000	16	3.8
Education level of parent	GCE O/L	220	52.1
	GCE A/L	165	37.0
	Degree	46	10.9

Table 2 - Distribution of Clinical information Characteristics (n=422)

Variable	Characteristic	Number	%
Malocclusion	Class 1	140	33.2
	Class 2 Division 1	201	47.6
	Class 2 Division 2	13	3.1
	Class 3	68	16.1
Severity of malocclusion (IOTN)	Mild need	28	6.6
	Moderate need	151	35.8
	Severe need	139	32.9
	Extreme need	104	24.6
Reason for seeking treatment (by patient)	Esthetic problem	302	71.6
	Functional problem	33	7.8
	By a referral	87	20.6
Reason for seeking treatment (by patient) (n=387)	Esthetic problem	280	72.4
	Functional problem	30	7.8
	By a referral	77	19.9

First, analyses (Table 1) focused on the socio-demographic characteristics of the study sample. Majority of the patients belonged to the 15-19 year age group and it was 44.8%. Followed by, 39.6% and 11.6% in the sample were in 10-14 year and 20-24 year age categories respectively. In this sample, 65.4% were female and 90% were sinhala participants. Majority (51.9%) belonged to 25000-50000 LKR income category. Most of the parents of participants have studied up to O/L.

Table 2 mainly focused on distribution of clinical characteristics of the study sample. Majority (47.6%) had class II Division 1 malocclusion, followed by 33.2% had class I malocclusion and 16.1% had class III malocclusion. In the study group 35.8% had moderate need for orthodontic treatment according to IOTN. 32.9% and 24.6% had severe need and extreme need respectively. Most of the patients have seeked orthodontic treatment due to esthetic reasons which is accounted for 71.6%. Similarly the majority of parents (72.4%) considered orthodontic treatment for their kids due to esthetic reasons.

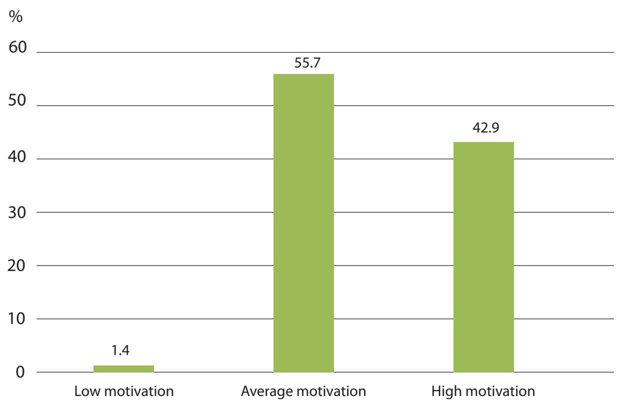

Chart 1 - Level of motivation of the patients Mean 46.28, SD 8.275, Minimum 15, Maximum 60

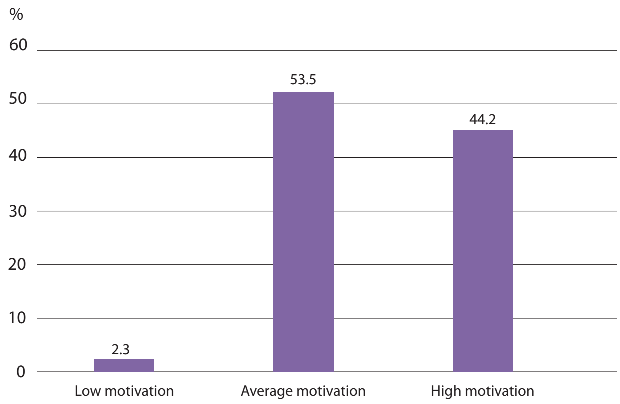

Chart 2 - Level of motivation of the parents Mean 42.43, SD 7.942, Minimum 11, Maximum 55

Level of motivation of the patients was calculated using scores in the Likertt scale. Total level of motivation of the patient scored from 12-60. Those who scored 12-23 were taken as low motivation group. Average motivation group included from 24-48. Those who scored >48 taken into high motivation group.

Further more, level of motivation of parents was calculated similarly but total level of motivation scored from 11-55. Those who scored 11-21 were included in the low motivation group and 22-44 and >44 were taken as average motivation group and high motivation group respectively.

According to chart 1, the majority of patients (55.7%) had average motivation. Secondly there's a considerable amount of patients who had high motivation which was accounted for 42.9%.

Level of motivation of the parents also showed similar pattern, 53.5% had average motivation and 44.2% had high motivation. (chart 2)

Table 3 – Statistical Association between Level of motivation of the Patient with Demographic factors (n=422)

	Level of motivation of the patient				
Age	Low & Average motivation (n=241)		High motivation (n=181)		Significant
	No	%	No	%	
< 15 Years	99	**59.3%**	68	40.7%	X^2 = 0.532, Df=1 p= 0.466 NS
= >15 Years	142	55.7%	113	**44.3%**	
Gender					X^2 = 0.016,Df=1, p= 0 .898 NS
Male	84	**57.5%**	62	42.5%	
Female	157	56.9%	119	**43.1%**	
Ethnicity					X^2 = 0.105, Df=1, p=0.746 NS
Sinhala	218	57.4%	162	**42.6%**	
Non Sinhala	23	**54.8%**	19	45.2%	
Incomes					X^2 = 0.238,Df=1, p= 0.626 NS
Rs. =< 50,000	186	**57.8%**	136	**42.2%**	
> Rs. 50,000	55	55.0%	45	**45.0%**	
Education					X^2 = 0.016,Df=1, p= 0.900 NS
Passed O/L	125	56.8%	95	**43.2%**	
Passed A/L & Degree	116	**57.4%**	86	42.6%	

X2= Chi square value S= Significant df= Degree of freedom NS=Not Significant

Statistical associations between demographic characteristics and level of motivation of the patients were analyzed using Chi square test.(table 3)

There was no statistically significant difference between age category and Level of motivation of the Patient in the study group. Study participants who were less than 15 years had Low & Average motivation compared to age more than 15 years had High motivation (p=0.466) but not statistically significant association.

Similarly there was no statistically significant difference between gender,ethnicity,level of income and education level of parents and the Level of motivation of the patient in the study group.

Table 4 – Statistical Association between Level of motivation of the Patient with Clinical factors (n=422)

	Level of motivation of the patient				
Malocclusion	Low & Average motivation (n=241)		High motivation (n=181)		Significant
	No	%	No	%	
Class 1	73	52.1%	67	**47.9%**	X^2 = 2.600,Df=2, p= 0.273 NS
Class 2	125	58.4%	89	41.6%	
Class 3	43	**63.2%**	25	36.8%	
Severity of malocclusion (IOTN)					X^2 = 9.310,Df=3, p= 0 .025 NS
Mild need	22	**78.6%**	6	21.4%	
Moderate need	77	51.0%	74	**49.0%**	
Severe need	86	61.9%	53	38.1%	
Extreme need	56	53.8%	48	46.2%	
Reason for seeking treatment (by patient)					X^2 =31.422,Df=2, p= 0 .000 NS
Esthetic problem	143	48.7%	155	**51.3%**	
Functional problem	24	72.7%	9	27.3%	
By a referral	70	**80.5%**	17	23.4%	
Reason for seeking treatment - by parent (n=387)					X^2 = 20.427, Df=2, p= 0.000 NS
Esthetic problem	141	50.4%	139	**49.6%**	
Functional problem	22	73.3%	8	26.7%	
By a referral	59	**76.6%**	18	23.4%	

Further analysis was done to find out statistical association between the clinical factors and the level of motivation of the patients. (table 4) There was no significant statistical difference between type of malocclusion and the level of motivation of the patients.

On the other hand, there was a statistically significant difference between severity of the malocclusion and the level of motivation of the patient.(p=0.025).

Further more, there was a statistically significant difference between the reason for seeking treatment by patient and the level of motivation of the patient(p=0.000). Similarly there was a statistically significant difference between the reason for seeking treatment by parent and the level of motivation of the patient(p=0.000)

Table 5 – Statistical Association between Level of motivation of the parents with Demographic factors (n=387)

Level of motivation of the patient					
Age	Low & Average motivation (n=216)		High motivation (n=171)		Significant
	No	%	No	%	X^2 = 0.440, Df=1 p= 0.507 NS
< 15 Years	90	53.9%	77	**46.1%**	
= >15 Years	126	**57.3%**	94	42.7%	
Gender					X^2 = 0.532,Df=1, p= 0.466 NS
Male	81	**58.3%**	58	41.7%	
Female	135	54.4%	113	**45.6%**	
Ethnicity					X^2 = 0.176, Df=1, p=0.675 NS
Sinhala	193	55.5%	155	**44.5%**	
Non Sinhala	23	**59.0%**	16	41.0%	
Incomes					X^2 = 1.581,Df=1, p= 0.209 NS
Rs. =< 50,000	160	54.1%	136	**45.9%**	
> Rs. 50,000	56	**61.5%**	35	38.5%	
Education					X^2 = 0.960,Df=1, p= 0.327 NS
Passed O/L	113	53.6%	98	**46.4%**	
Passed A/L & Degree	103	**58.5%**	73	41.5%	

X2= Chi square value S= Significant df= Degree of freedom NS=Not Significant

According to chi square analysis, there was no statistically significant association between demographic factors and the level of motivation of the parents.(table 5)

Table 6 – Statistical Association between Level of motivation of the parents with Clinical factors (n=387)

Level of motivation of the patient					
Malocclusion	Low & Average motivation (n=241)		High motivation (n=181)		Significant
	No	%	No	%	X^2 = 3.887,Df=2, p= 0.143 NS
Class 1	71	59.2%	49	40.8%	
Class 2	103	51.2%	98	**48.8%**	
Class 3	42	**63.6%**	24	36.4%	
Severity of malocclusion (IOTN)					X^2 =17.503,Df=3, p= 0 .001 NS
Mild need	22	78.6%	6	21.4%	
Moderate need	69	53.1%	61	**46.9%**	
Severe need	86	63.7%	49	36.3%	
Extreme need	39	41.5%	55	58.5%	
Reason for seeking treatment (by patient)					X^2 =4.696,Df=2, p= 0 .096 NS
Esthetic problem	142	25.4%	129	**47.6%**	
Functional problem	17	58.6%	12	41.4%	
By a referral	57	**65.5%**	30	34.5%	
Reason for seeking treatment - by parent (n=387)					X^2 = 6.818, Df=2, p= 0.033 NS
Esthetic problem	145	51.8%	135	**48.2%**	
Functional problem	19	63.3%	11	36.7%	
By a referral	52	**67.5%**	25	32.5%	

Statistical analysis was carried out to assess the association between the level of motivation of the parents and the clinical factors.(table 6)It revealed that there was a statistically significant association between the severity of malocclusion and the level of motivation of the parent.(p=0.001). Similarly there was a statistically significant association between reason for seeking treatment by parent and the level of motivation of the parent.(p=0.033)

Table 7 – Statistical Association between reason for seeking treatment (by patient) with reason for seeking treatment (by parent) (n=387)

	Reason for seeking treatment - by patient						Significant
Reason for seeking treatment - by parent (n=387)	Esthetic problem (n=271)		Functional problem (n=29)		By a referral (n=87)		Cannot calculate statistical significant level as 5 cells are less than 5 numbers
	No	%	No	%	No	%	
Esthetic problem	268	95.7%	0	0.0%	12	4.3%	
Functional problem	0	0.0%	28	93.3%	2	6.7%	
By a referral	3	3.9%	1	1.3%	73	94.8%	

Table 8 – Statistical Association between Level of motivation of the Patient with Level of motivation of the Parent (n=387)

	Level of motivation of the Patient				Significant
Level of motivation of the Parents	Low & Average motivation (n=222)		High motivation (n=165)		X^2 = 134.792, Df= 1 p = 0.000 NS
	No	%	No	%	
Low & Average motivation	180	83.3%	36	16.7%	
High motivation	42	24.6%	129	75.4%	

According to the analysis(table 8), there was a statistically significant association between the level of motivation of the parents and the level of motivation of the patients.(p=0.000)

Table 9 – Correlation association with Level of motivation of the Patient and Level of motivation of the Parent

		Level of motivation of the Patient	Level of motivation of the Parents
Level of motivation of the Patient	Pearson Correlation P Value Number	1 422	**0.804** **0.000**
Level of motivation of the Patient	Pearson Correlation P Value Number	**0.804** **0.000** 387	1 387

** Correlation is significant at the 0.01 level (2-tailed).

There is a statistical significant association **(p value is 0.000)** and positive High correlation (according to Pearson test) between Level of motivation of the Patient and Level of motivation of the Parent as Pearson correlation value (r value) is **0.804**

Cutoff value for correlation

0.0 – 0.299 - Mild correlation

0.3 – 0.5 - Moderate correlation

>0.5 - High correlation

DISCUSSION

According to literature, facial aesthetics was found to be a major determinant of self and social perceptions. Aesthetic factor is the most important motivational factor for orthodontic treatment.[13] Favourable facial appearance is said to be more attractive and socially well acceptable.[5] Recent systematic review showed that facial attractiveness as the main motivational factor in orthodontic treatment.[14] One study pointed out that according to the patients' view, teeth were second in importance only to facial appearance.[12] People with more self-confidence and high self- esteem are satisfied with their faces and people who are dissatisfied with their facial appearance worry mainly about their teeth. So not surprisingly , most people believe that orthodontic treatment will improve their dentofacial appearance.[12]

[15] Similarly in this study, the main reason for seeking orthodontic treatment by both patients and parents was esthetic concerns and it accounted for 71.6% and 72.4% respectively. Secondly most of the patients and parents have seeked orthodontic treatment as they have been referred from primary dental care professionals. There was very minor amount of patients and parents who seeked orthodontic treatment due to functional problems.Further more, this study showed that there was a statistically significant association between the reason for seeking treatment by both patients and parents and the level of motivation of patients.

In some studies, they have showed that Level of motivation for orthodontic treatment was found to be correlated with gender. In a study, it was found that expectations of orthodontic treatment of males and females were different. Even though both males and females had a inspiration to improve their self image and oral functions, males wanted to improve their social well being as well.[16] Furthermore, it was noted that improvement of appearance was taken by females as an own reward whereas males believed in social gains.[16] Evidence showed that girls were concerned more about crowding, spacing and rotations than boys.[17] Previous studies also showed that females were more dissatisfied with their appearance than males and females wanted to go for fixed appliances more often than males.[18 19] In contrast, this study showed that there was no statistically significant difference between the gender and the level of motivation of patients and parents.

Motivation for orthodontic treatment was also found to be correlated with age according to some literature.Concern about facial aesthetics and appearance increased with age, and has the peak in mid teens. Adults were more dissatisfied with their facial appearance than younger children.[20] Adult patients are mostly unhappy about their dental appearance and it is the main factor which motivated them to seek orthodontic treatment at this stage of their life.[21]But this study showed that there was no statistically significant difference between the age group and the level of motivation.

Level of education of the patients and parents also has an impact on motivation towards orthodontic treatment. One of the studies concluded that when educational background gets better, patients and parents think that improvement of oral health is equally important as along with the improvement of dentofacial aesthetics.[22] Also individuals in higher socioeconomic classes seeked orthodontic treatment mainly to improve their dental esthetics.[23] In contrast , findings of this study revealed that there was no statistically significant difference between socioeconomic status (income of the family and level of education of the parents) and the level motivation of the patients.

Type and severity of the malocclusion has some influence in motivation for orthodontic treatment. Psychological impact of dental appearance increases as severity of malocclusion increases and it plays a major role in seeking orthodontic treatment.[24] Crowding , extreme deep bite and increased overjet were the most unfavorable aspects of malocclusion as perceived by the patients.[25] Studies pointed out that the children with an overjet of more than 7mm, anterior crowding and deep bite were more likely to be teased by other children[18] Patients with class 2 malocclusion seemed to be more motivated to seek treatment than patients with class 3 malocclusion.[26]

Surprisingly this study found that there's no statistically significant difference between type of malocclusion and the level of motivation. But this study revealed that there's statistically significant difference between severity of the malocclusion and the level of motivation. Participants who had moderate and severe need had high motivation level when compared with mild need who had low motivation.

Evidence showed that most parents expected to improve their children's self esteem and oral health by orthodontic treatment.[27] Both children and their parents perceived similar reasons for orthodontic treatment.[28] But in contrast some studies demonstrated that parents wanted orthodontic treatment for their children more than the children desired it for themselves. In addition, many parents and children tend to receive orthodontic treatment regardless of the need.[29] Also the influence of a mother has shown to have a more impact for treatment motivation than that of a father.

In this study, it was found that there is a statistically significant association between the level of motivation of the patient and the reason for seeking treatment by both the patient and the parent. Moreover there was a statistically significant association between level of motivation of the parent and the reason for seeking treatment by parent. Finally, this study revealed that there was a statistically significant association and positive high correlation between the level of motivation of the patient and the level of motivation of the parents.

It is recommended that orthodontic clinics incorporate an initial assessment of both patient and parent motivation during the treatment planning phase. This could help tailor communication strategies, improve patient compliance, and enhance treatment outcomes.Additionally, creating awareness programs about the impact of malocclusion and the benefits of orthodontic treatment may further improve motivation levels, especially among less-informed patient groups. Further study which analyze the relationship between level of motivation and satisfaction with the treatment outcome can be performed.

CONCLUSIONS

1. There were statistically significant relationships between level of motivation of the patient and

a)the severity of the malocclusion

b)the reason for seeking treatment by the patient

c)the reason for seeking treatment by the parent

2. There were statistically significant relationships between level of motivation of the parent and

a)the severity of malocclusion of the patient

b)the reason for seeking treatment by parents

3. There was a statistically significant association and positive high correlation between the level of motivation of the patient and the level of motivation of the parent

4. The motivation levels of patients and parents are closely associated and vary significantly depending on the reason for seeking treatment and the severity of the malocclusion of the patient.

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Effects of pumice prophylaxis on retention of orthodontic brackets in a conventional etch and prime system in patients attending the Orthodontic clinic, National Dental Hospital (Teaching), Sri Lanka.

Ramanayaka MNJA[1], Senadeera WM[2], Perera I[3], Jayasekara P[4], Paranthamalingam K[5]

[1]Orthodontic unit, National Dental Hospital (Teaching), Sri Lanka

[2]Dental multispecialty center, No 16, Ward Place, Colombo 7

[3]Preventive oral health unit, National Dental Hospital (Teaching), Sri Lanka

[4]Research and surveillance unit, Institute of Oral Health, Maharagama, Sri Lanka

ABSTRACT:

Objectives - To compare the bond failure rates of orthodontic brackets and patient perceived discomfort during the bonding procedure of brackets between pumiced and non-pumiced groups of teeth in conventional etch and prime system in the Orthodontic unit, National Dental Hospital (Teaching), Sri Lanka.

Methods - A split mouth randomized controlled trial was conducted at the Orthodontic unit of the National Dental Hospital (Teaching), Sri Lanka. Seventy-three patients receiving fixed appliances with metal brackets on both arches were enrolled. In each participant, two quadrants were randomly allocated to pumice prophylaxis prior to etching, while the contralateral quadrants were bonded without pumice prophylaxis. Bond failures were recorded per tooth over a six-month follow-up period. Patient perceived discomfort during the bonding was categorized into five levels. The chi-square test was used to compare bond failure rates and discomfort levels, while the paired t-test was used to compare the mean time to bond failure. Data was analyzed using Statistical Product and Service Solution (SPSS) version 25.

Results - A total of 1259 teeth were bonded, with 631 teeth in the pumiced group and 628 teeth in the non-pumiced group. Ten bond failures occurred in each group, giving failure rates of 1.584 percent in the pumiced group and 1.592 percent in the non-pumiced group. There was no statistically significant difference in bond failure rates in pumiced and non-pumiced groups: ($p=0.9909$). The patient-perceived discomfort during bracket bonding in pumiced group did not differ significantly from non-pumiced group ($p=0.754$). Age and gender were not significantly associated with the bracket failures in either group and the overall duration of bonded bracket fracture among two groups did not reveal significant differences ($p>0.05$).

Conclusion - Within the limitation of this clinical study, pumice prophylaxis before conventional etch and prime bonding, did not reduce bracket bond failure. Patient reported discomfort during bonding was minimal and similar between groups. Therefore, suggested by evidence generated by this study, pumice prophylaxis did not offer an advantage over not following this procedure pertaining to conventional etch and prime bonding.

Keywords : Orthodontic brackets. Pumice prophylaxis. Bond failure. Split mouth randomized trial. Patient discomfort.

Trial registration number - SLCTR/2024/034

INTRODUCTION

Orthodontic treatment provision largely relies on fixed appliance therapy, where brackets are bonded directly to the teeth. Obtaining adequate bond strength is paramount and according to Reynolds et al(1), 5.9 – 7.9 MPa bond strength is required for successful bonding. Bond failure causes many disadvantages, especially increasing treatment duration. Re-bonding a failed bracket, increases treatment time by a mean of 0.3 months(2). It also places an additional burden on patients, necessitating more visits and increasing the workload of already overburdened orthodontic clinics and increasing treatment costs for both patients and the practitioner.

Incidence of bond failure varies widely ranging from 0.6% - 28.3%(3), influenced by both patient- and operator-related factors. Patient factors comprise enamel defects, age, compliance, oral hygiene, jaw, location of teeth, overbite, and overjet. Operator-related factors include etching pattern, etchant concentration, type of primer and composite resin, curing light and duration, contamination with blood or saliva, bracket material and pre-treatment procedure such as bleaching or chlorhexidine use(4).

Bonding relies on mechanical locking of adhesive resin between the bracket base and the irregularities in the enamel surface by tag formation. This usually requires enamel preparation with acid etching before applying the adhesive resin. Pumice prophylaxis prior to etching is a long-established component of enamel preparation, performed to remove plaque and acquired pellicle which may interfere with proper etching. In 1973, scanning electron microscopy studies by Miura et al(5) found that pumice prophylaxis does remove this enamel pellicle and highlighted the necessity of this step. However, prophylaxis adds steps, increases clinical time, and may increase patient discomfort, particularly in lower incisors with limited access.

The question of whether pumice prophylaxis is necessary for adequate bracket retention has therefore been revisited repeatedly over the last three decades and later several studies have shown that it was not clinically significant in reducing bond failures in conventional etch and prime system(6–8). However, with the introduction of self-etching primers (SEP), pumice prophylaxis regained attention as it increased bond strength with SEP(9–11). Therefore, the need for pumice prophylaxis created an unresolved controversy in bonding over the years as some studies demonstrated favorable outcomes while others contradicted.

Although there are studies conducted in other countries that compared the bond failure rates in conventional etch and prime systems with or without pumice prophylaxis(9-11), no such studies have been conducted among Sri Lankan orthodontic patients and still the pumice prophylaxis is widely used. Evidence from other countries may not be directly applicable to Sri Lankan public health sector context due to differences in levels of oral hygiene, socioeconomic conditions and healthcare delivery systems. This highlights a significant evidence gap within the local context and this study was undertaken to address this and the findings of this study would strengthen the evidence to modify pumice prophylaxis practices within the overburdened public sector orthodontic clinic context in Sri Lanka. Additionally, it evaluated patient-perceived discomfort during bonding, an outcome relevant to patient-centered care but not consistently included in bonding trials.

MATERIALS AND METHODS

This study was a split mouth randomized controlled trial conducted at the Orthodontic clinic of the National Dental Hospital (Teaching), Sri Lanka. The study protocol (version 3 – 15/08/2024) specified a split mouth design to control inter individual differences in enamel quality, salivary environment, oral hygiene, and other patient level characteristics. Participants were patients attending the orthodontic clinic of National dental hospital (Teaching), Sri Lanka who were aged 12 years and above and the inclusion criteria were having fully erupted incisors, canines, and premolars and planned for fixed appliance therapy with metal brackets on both upper and lower arches. Patients with a history of previous orthodontic treatment, having poor oral hygiene, physically or mentally compromised, with craniofacial anomalies, having incisors, canines and premolar teeth with labial restorations, decalcification, enamel defects and other developmental defects or having prosthetic replacement of teeth, having teeth which are completely out of arch labially or lingually were excluded. Data collection took place from 1st of November 2024 to 1st of December 2025 and the study was completed as planned with no early termination.

Sample size calculation was done using the formula,

$$N = \frac{P1(1-P1) + P2(1-P2) \times f(\alpha\beta)^{(12)}}{(P1-P2)^2}$$

P1- % of success expected in the control group based on a published study = 66.7% [13]

P2- % of success expected in the intervention group based on the same published study = 75.7%

α-Level of significance used for detecting a difference (0.05 two sided)

β-Type 2 error when power is set at 90%

f -function of αβ = 10.5 [12]

The final sample included 73 patients to have minimum 584 teeth per group. In each new patient who was recruited in the study, the two quadrants that should be pumiced were selected by simple randomization using a coin toss by the operator at the time of bonding. Pumiced group teeth underwent pumice prophylaxis(Intervention) prior to enamel etching and non-pumiced group(Comparator) were bonded using the same conventional etch and prime system, but without the pumice prophylaxis step. All other steps were kept consistent. Due to the split-mouth study design, blinding of both the patients and the operator was not feasible and allocation concealment was not implemented.

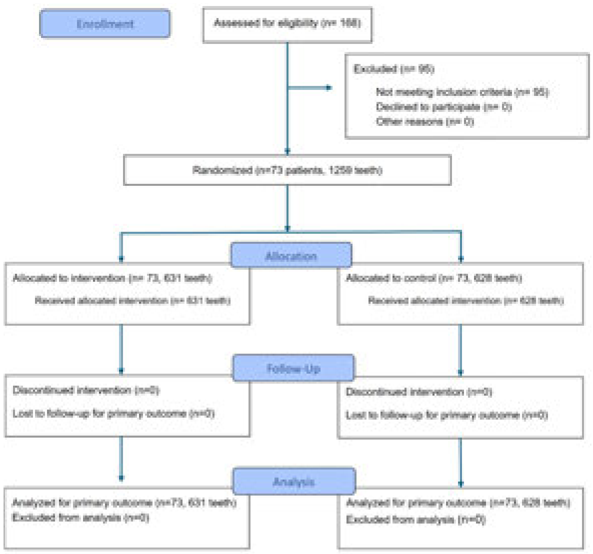
3M™ 0.022 MBT metal brackets were bonded on the prepared tooth surface. Then initial Nickel Titanium arch wires of size 0.012'' were placed on the same day after confirming that there were no occlusal interferences and were ligated with elastomeric ligatures. One operator undertook all these clinical works and at the end of bonding procedure, standardized post-operative instructions which also include measures to prevent bond failure, were given to all the patients. All the patients were asked to report bond failures as soon as they occur and they were given an extra appointment to re-bond the bracket. Otherwise, patients were reviewed on routine visits which were given 6 weekly.

Bond failures were recorded for 6 months after the initial bonding in each patient, as most of the failures occur in the first few months[4,14]. Bracket failures were documented with the tooth number, site, date of debonding and with the details of patients. Those brackets were re-bonded immediately and were not considered for further observation in the study. No adverse events or harms were observed during the study period.

The primary outcome was bond failure rate among pumice applied teeth vs non-pumiced teeth within six months after initial bonding and the secondary outcomes were patient perceived discomfort during the initial bonding of brackets and the factors associated with bond failure such as age, gender and duration for failure of bracket after the bond up. Statistical analysis of data was performed using Statistical Product and Service Solution (SPSS) version 25. Confidence level was 95% and difference between two groups were considered as significant if the p value was less than 0.05.

At the appointment of initial bonding of brackets, informed written consent was obtained from the adult patients and, from the parents/legal guardian in case of a minor aged 12-18 years along with the assent from the child. Ethical clearance of the study was obtained from the ethical review committee of the Faculty of Medicine; University of Colombo and the study was conducted in accordance with relevant guidelines and regulations. The study was registered in the clinical trial registry of Sri Lanka (SLCTR/2024/034, universal trial number - U1111-1302-3144) and the study protocol remained unchanged throughout the study and is available upon request.

ANALYSIS



A total of 168 participants were assessed for eligibility, of whom 73 were recruited. Among them, 631 teeth received pumice prophylaxis and 628 teeth served as controls. Participant flow through the study is shown in the Consolidating Standards of Reporting Trials (CONSORT) flowchart(15) (Fig 1). There were no withdrawals from the study and all bonded teeth were included in the analysis according to the allocated groups. There was no missing data. The age range of the sample was 11 to 35 years, with a mean age of 18.6 years and standard deviation 5.1. There were 47 females and 26 males. A total of 1259 teeth were bonded. Demographic and clinical characteristics of each group are shown in table 1a, 1b. The de-identified datasets generated during the current study are available from the corresponding author on reasonable request.

(i) Table 1a

Variable	Number	%
Gender		
Males Females	26 47	35.6 64.4
Total	**73**	**100.0**
Dentition		
Upper Lower	313 318	49.6 50.4
Total	**631**	**100.0**
Fractured brackets		
Upper teeth Lower teeth	6 4	
Total	**10**	**100.0**

(ii) Table 1b

Variable	Number	%
Gender		
Males Females	26 47	35.6 64.4
Total	**73**	**100.0**
Dentition		
Upper Lower	312 316	49.7 50.3
Total	**628**	**100.0**
Fractured brackets		
Upper teeth Lower teeth	6 4	
Total	**10**	**100.0**

Comparing bond failure rates among the two groups

Ten bond failures occurred in each group and the failure rate was 1.584 percent for the pumiced group and 1.592 percent for the non-pumiced group. The reported absolute difference between failure rates was 0.008 percent with a 95 percent confidence interval from minus 1.4870 percent to 1.5068 percent. The chi square statistic was 0.000 with 1 degree of freedom and a reported p value of 0.9909, indicating no statistically significant difference in bond failures between the groups. Overall bond failure rate was 1.58 percent.

Patient-perceived discomfort during bond up

Table 2 compares patient-perceived discomfort during bonding and it was minimal among both groups. In the pumiced group, 67 (91.8 %) patients reported no discomfort and 6 (98.2%) reported slight discomfort. In the non-pumiced group, 68 (93.2%) reported no discomfort and 5(6.8%) reported slight discomfort. None of the patients reported discomfort level categorized as 'high'. The patient-perceived discomfort during bracket bonding in pumiced group did not differ significantly from non-pumiced group (p=0.754).

(iii) Table 2

Patient perceived discomfort	Group				Chi-square value	p-value
	Pumiced		Non-pumiced		0.098	0.754
	N	%	N	%		
None	67	91.8	68	93.2		
Slight	6	8.2	5	6.8		
Total	73	100.0	73	100.0		

Factors associated with bond failures

Table 3a and 3b show that the gender and age were not significantly associated with the bracket failures in either group. Normality of bracket failure duration was assessed using the Shapiro–Wilk and Kolmogorov–Smirnov tests and the distribution of data in both the pumiced and non-pumiced groups did not significantly deviate from normality (p>0.05). Therefore, a paired t-test was performed to compare bracket failure duration between pumiced and non-pumiced groups. As shown in Table 4, paired comparison by paired t-test among pumiced and non-pumiced groups by overall duration of bonded bracket fracture, fracture of bonded brackets on upper teeth and lower teeth among two groups did not reveal significant differences (p>0.05).

(iv) Table 3a

Bracket dislodgement in pumiced group	Gender				p-value (Fishers Exact test)
	Male		Female		0.266
	N	%	N	%	
Not Present	21	80.8	43	91.5	
Present	5	19.2	4	8.5	
Total	26	100.0	47	100.0	
Bracket dislodgement in non-pumiced group	**Gender**				**p-value (Fishers Exact test)**
	Male		Female		0.245
	N	%	N	%	
Non present	25	96.2	40	85.1	
Present	1	3.8	7	14.9	
Total	26	100.0	47	100.0	

(v) Table 3b

Bracket dislodgement in pumiced group	Age				p-value (Fishers Exact test)
	<18 years		≥18 years		0.723
	N	%	N	%	
Not Present	25	84.8	36	90.0	
Present	5	15.2	4	10.0	
Total	33	100.0	40	100.0	
Bracket dislodgement in non-pumiced group	Age				p-value (Fishers Exact test)
	<18 years		≥18 years		1.00
	N	%	N	%	
Non present	29	87.9	36	90.0	
Present	4	12.1	4	10.0	
Total	33	100.0	40	100.0	

(vi) Table 4

Variable	Mean	95% Confidence Interval of the difference		t-value	p-value
		Lower	Upper		
Overall duration taken for bonded bracket fracture among pumiced and non-pumiced groups	-0.444	-2.370	1.481	-0.532	0.609
Duration taken for bonded bracket fracture of upper teeth among pumiced and non-pumiced groups	1.250	-2.278	4.778	1.127	0.342
Duration taken for bonded bracket fracture of lower teeth among pumiced and non-pumiced groups	-1.750	-4.468	0.968	-2.049	0.133

DISCUSSION

Present study produced locally generated evidence on impact of pumice prophylaxis on bond failures. According to the findings of the study, bond failure rates were almost identical between the pumiced and non-pumiced sides, and the confidence interval around the difference suggested no clinically relevant advantage for adding pumice prophylaxis in this setting. The present findings are consistent with several clinical investigations that questioned the necessity of pumice prophylaxis. Barry reported that omission of pumice prophylaxis did not increase clinical failure rates in their patient cohort (7). Lindauer and colleagues also found that pumice prophylaxis did not materially improve clinical bracket retention, despite measurable differences in surface appearance under microscopy (8). Ireland and Sherriff observed that pumicing was not necessary to achieve acceptable clinical performance when bonding with either a resin modified glass poly alkenoate cement or a conventional composite (13). Overall bond failure rate was 1.58 percent which was lower than the other studies of literature.

The consistency of these findings across different settings suggests that acid etching may itself be sufficient for surface conditioning in many clinical situations, at least when enamel surfaces are reasonably clean and moisture control is adequate. The present study extends this evidence to the Sri Lankan public sector clinical environment, where the potential operational benefits of omitting non-essential steps could be important.

Discomfort during bonding was minimal, and the distribution of responses was similar in both groups. This suggests that pumice prophylaxis, as performed in this clinic, did not produce a noticeable increase in discomfort for most patients. However, the outcome scale in practice captured only two response categories, so it may not have been sensitive to small differences. More granular tools, such as a visual analogue scale, could provide greater discrimination in future work, especially if the aim is to quantify incremental discomfort from specific procedural steps.

A recent retrospective study evaluated factors related to bracket bond failure and identified location specific and patient related associations(16). Similar findings were reported by another retrospective study which reported significantly higher bracket bond failure rates among younger patients compared to older patients, increased overbite compared to other malocclusion types and brackets placed on mandibular molars and premolars compared to other teeth(17). However, the results of the current study failed to produce any statistically significant association with the patient factors like age and gender with bond failures. Differences in findings could be attributed to differences among orthodontic patients with regard to patient related and location specific factors which could interfere with bond failures. There was no significant difference for the duration taken for bracket failures between pumiced and non-pumiced groups in overall and in upper and lower teeth. This finding further strengthened evidence for lack of influence of pumice prophylaxis for better bond retention.

This study has several strengths and limitations. The split-mouth randomized controlled design minimized inter-individual variability and enhanced internal validity. Standardization of procedures by a single operator reduced technical variability and inclusion of patient-centered outcomes alongside clinically relevant measures adds to the practical relevance of findings. But blinding was not feasible due to the split-mouth design, which may introduce performance bias. Additionally, the findings may not be generalizable beyond similar public sector clinical settings.

CONCLUSION

Pumice prophylaxis before a conventional etch and prime bonding protocol did not reduce bracket bond failure within six months in patients treated at the Orthodontic clinic of the National Dental Hospital Teaching, Sri Lanka. Failure rates were low and nearly identical between pumiced and non-pumiced teeth. Further, patient-perceived discomfort during bonding was minimal in both groups. Therefore, evidence generated by this study substantiated that pumice prophylaxis did not offer an advantage over not following this procedure pertaining to conventional etch and prime bonding. These findings support consideration of omitting routine pumice prophylaxis when bonding brackets with a conventional etch and prime system in similar clinical settings.

CONFLICT OF INTEREST

The authors declare that they have no known conflict of interests or personal relationships that could have appeared to influence the work reported in this paper.

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Age of patients when first referred to the Orthodontic Unit, National Hospital Kandy with maxillary impacted canines: Clinical Audit

Ariyaratne A[1], Wettasinghe D P[2], Jayasinghe R D[3]

[1]Senior Registrar in Orthodontics, National Hospital, Kandy, Sri Lanka

[2]Consultant Orthodontist, National Hospital, Kandy, Sri Lanka

[3]Chair Professor of Oral Medicine and Periodontology, Dept. of Oral Medicine and Periodontology, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka

ABSTRACT:

Maxillary canines are the second most frequently impacted teeth, with a prevalence of 2%. Early referral allows for the use of interceptive measures to prevent impaction, thereby reducing the likelihood of requiring orthodontic treatment or surgical intervention and minimizing complications associated with prolonged impactions. This retrospective clinical audit aimed to assess whether patients with impacted maxillary canines were referred by the recommended age of 12 or younger, by the guidelines set by the Royal College of Surgeons.

This audit reviewed patient records from the Orthodontic Clinic at the National Hospital Kandy for the years 2018 and 2019. Data collected included the patient's age, sex, referral source, and diagnosis at the time of referral. Among the 6,405 records examined, 234 cases involved impacted maxillary canines.

Impacted maxillary canines represented 3.65% of all referrals. Of the 234 patients identified, only 40 (17.09%) were aged 12 or younger. The most common age of presentation was 14 years. Just 30 referring clinicians (12.8%) noted the presence of impacted maxillary canines in their referral letters, and only one included an appropriate radiograph.

A considerable proportion of patients were referred beyond the age recommended by the Royal College of Surgeons guidelines. Enhancing awareness among referring clinicians about when to suspect and refer cases of impacted maxillary canines is crucial. The key findings of this audit should be communicated to clinicians, along with a referral algorithm to support timely identification and referral. A follow-up audit cycle is recommended to evaluate improvements in referral practices.

Keywords – impacted maxillary canines, clinical audit.

INTRODUCTION

Maxillary canines play a key role in dentition from an aesthetic and functional standpoint. They are important in facial aesthetics as they provide support to the upper lip and the facial muscles. Additionally, canine guidance in occlusion helps prevent potentially harmful horizontal forces on the posterior teeth during lateral movements of the mandible. (1)

Maxillary canines are the second most commonly impacted teeth following the mandibular third molar (2). The incidence of maxillary impacted canines ranges from 0.8 – 2.8% (3). Impacted maxillary canines are more prevalent among females (4). 85% of impactions are palatal and 15% are buccal impactions (5).

Clinical assessment for maxillary canines should take place by palpation of the upper buccal sulcus from the age of 9 years. Suspicion of an impacted maxillary canine should arise if the canine bulge is not palpable in the upper buccal sulcus by 10 years of age. Canine bulge palpable in an ectopic position, presence of a firm retained deciduous canine, abnormal appearance of adjacent teeth (missing or diminutive maxillary lateral incisors) or abnormal position of adjacent teeth (flaring of maxillary lateral incisors) also indicate the possibility of an impacted maxillary canines (6-8).

According to the British Orthodontic Society Radiography guidelines, a radiographic assessment is advised by age 10 if there are clinical indications that the maxillary canine might be impacted. The Royal College of Surgeons (UK) strongly advises general dental practitioners to consult an orthodontist before commencing any treatment for impacted maxillary canines. Additionally, patients with suspected impaction should be referred to an orthodontist by the age of 12 or younger.

With timely referral, interceptive extraction of the primary maxillary canine can be performed to encourage proper eruption of the impacted permanent canine (9). Interceptive extraction is simple, cost-effective and can be easily performed. Research indicates that interceptive extractions are most likely to be successful in patients aged 10 to 13. The likelihood of success is especially high—up to 78%—when the permanent maxillary canine is positioned palatally within an uncrowded arch. In such cases, extracting the deciduous canine can effectively guide the permanent canine into its correct path of eruption (6, 7, 10) (Figure 1). Therefore, delayed detection or referral may result in impacted maxillary canines, potentially leading to significant consequences for the patients

Preventing impaction is more favourable than managing it after occurrence. Impacted canines also fall into the highest category of the Index of Orthodontic Treatment Need (IOTN = 5i). The management of impacted canines typically involves surgical intervention, either for extraction or exposure of the tooth. When exposed, the canine often requires orthodontic traction and extended treatment to achieve proper alignment. This approach is complex, time-consuming, and costly, and it may also negatively impact the periodontal health of the affected canin(9).

If not managed, impacted maxillary canines can pose significant risks, including root resorption and possible loss of adjacent permanent teeth. Studies report that the incidence of incisor root resorption due to ectopic canines ranges from 12.5% to 48%(5).

It is the responsibility of the general dental practitioner to ensure early diagnosis and prompt referral of potentially impacted maxillary canines. However, variability in referral patterns, diagnostic delays, or lack of awareness among general dental practitioners may result in late referrals, potentially compromising treatment outcomes.

This clinical audit aims to evaluate the age of patients when first referred to an orthodontist with impacted maxillary canines. By analysing referral patterns and comparing them to established guidelines and best practices, this audit seeks to identify potential gaps in the referral process and provide recommendations to improve early diagnosis and management. The findings will contribute to enhancing clinical practice, ensuring timely intervention, and ultimately improving patient care for individuals with impacted maxillary canines. The specific objectives of the study were to determine if the patients with impacted maxillary canines were referred at the appropriate age, with the correct diagnosis and to determine if the patients with impacted maxillary canine were assessed by an orthodontist in a timely manner.

MATERIALS AND METHODS

Patient admission records at the Orthodontic unit, NHK from the years 2018 and 2019 were assessed for the purpose of this study. Patients' age, sex, referral source, diagnosis at the time of referral and the time lapse between the date of referral and the date the patient was seen at the Orthodontic Unit, NHK was noted in a prepared structured data collection form. All collected data were checked for completeness, accuracy and consistency. Study was analysed by using SPSS version 26. This clinical audit was approved by the Ethics Committee of the National Hospital Kandy (NHK/ERC/114/2024).

Royal College of Surgeons (UK) Guidelines were used as the standard of care for referrals which recommended that all patients with suspected impacted maxillary canines be referred to an orthodontist by the age of 12 (11). British Orthodontic Society Radiology Guidelines (12) were used in determining the timing for orthodontist opinion after referral which recommended that referred patients should be seen within six months by an orthodontist.

British Orthodontic Society Radiology Guidelines was used as the gold standard for radiographic investigations for impacted canines which recommended carrying out radiographic investigation in all patients with suspected impacted maxillary canines who are aged 10 or above (12).

All collected data were checked for completeness, accuracy and consistency. The study was analyzed by using SPSS version 26. Quantitative data will be presented as mean +/- SD and qualitative data will be presented as frequency or percentage.

RESULTS

Figure 1

A – 13-year-old patient referred to the Orthodontic unit NHK for proclined upper teeth was found to have a palatally displaced canine and interceptive extraction of 53 done. B - 6 months following extraction. C – 12 months following extraction.

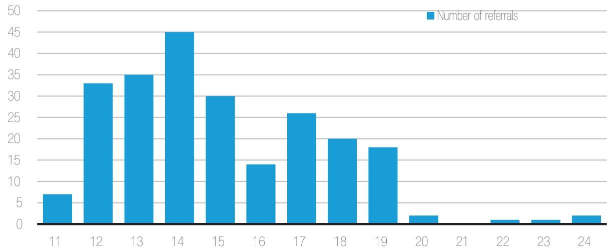

Figure 2

Six thousand four hundred five medical records of the orthodontic patients attending the orthodontic clinic, NHK were analyzed and 234 of them were presented with impacted maxillary canines. Impacted maxillary canines comprised 3.65% of total referrals. Out of the 234 patients, 167 (71%) were female patients and 67 (29%) were males. Of the 234 patients presented with impacted maxillary canines 40 (17.09%) were 12 years or below. The peak age of presentation was 14 years of age.

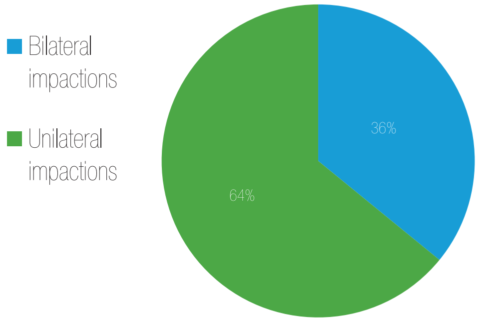

Figure 3

One hundred and fifty out of 264 patients (64%) had unilateral impaction of maxillary canine and 84 patients (36%) had bilateral impactions.

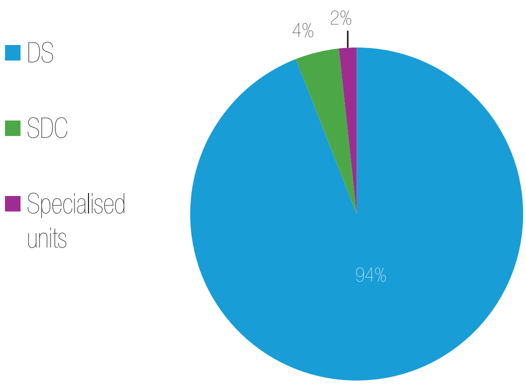

Figure 4

The majority of the patients were referred to the orthodontic unit by a general dental surgeon (94%). Out of 234 patients presented to the clinic with impacted canines, only 30 (12.8%) referring clinicians had mentioned the impacted maxillary canine in the referral letter. Only 1 referring clinician had referred with relevant radiographs.

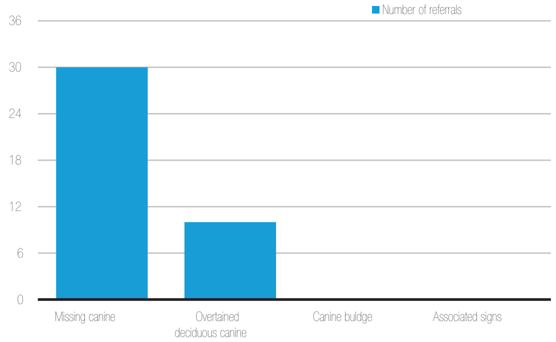

Figure 5

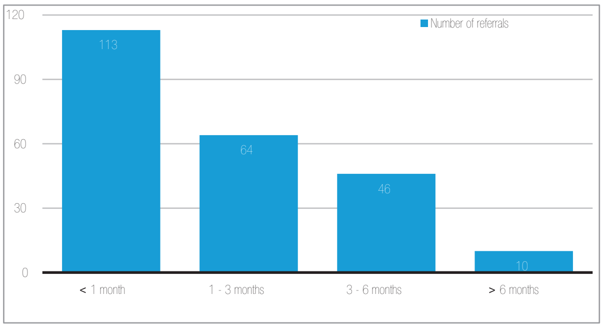

Figure 6

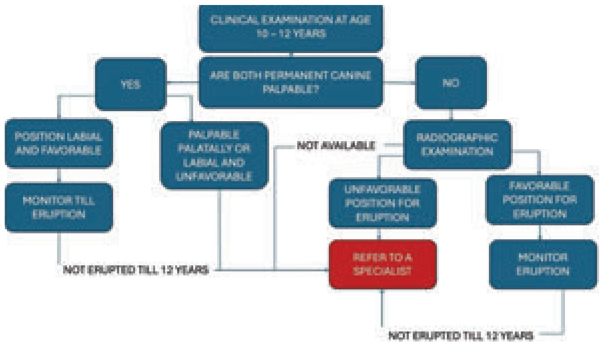

Figure 7

All 30 of the referrals mentioned the absent maxillary canine. Ten referrals (33.3%) commented on the presence or absence of the over-retained deciduous canine. There was no mention of positive or negative findings of canine bulge palpation or other associated signs. Only a single referring clinician had referred with relevant radiographs. (Figure 5)

One hundred thirteen of the 234 patients were seen by an orthodontist at the orthodontic unit NHK within a month of referral. 95% of the patients were assessed by an orthodontist within 6 months from the time of referral. There was a time-lapse of more than 6 months in 10 of the referrals. The reason for the delay in these patients was failure to keep up with their appointments. (Figure 6)

	CRITERIA	STANDARD	FULL FILLED CRITERIA	VARIANCE FROM STANDARD
Royal College of Surgeons (UK)	Patients referred by 12 years	100%	17.09%	-82.91%
British Orthodontic Society Radiology Guidelines	Appropriate radiograph taken for patients aged 10 and over	100%	0.427%	-99.57%
Locally agreed guideline	All patients should be seen by and orthodontist within 6 months	100%	91.45%	-8.55%

Table 1 – Side-by-side comparison of the results of the present study with the standards

DISCUSSION

The Royal College of Surgeons (UK) Guidelines recommend that all patients with suspected impacted maxillary canines should be referred to an orthodontist by the age of 12(11) and the British Orthodontic Society Radiology Guidelines recommend that radiographic evaluation be conducted for all patients aged 10 or older with suspected impacted maxillary canines. The present clinical audit was conducted whether the current referral systems in place comply with these standards and guidelines.

Only 3.65% of total referrals to the Orthodontic unit NHK, in the years 2018 and 2019 were impacted maxillary canines. The peak age of referral was 14 years which was similar to the results reported by Patel et al. Only 17.09% were referred on or before the age of 12 years as recommended by the Royal College of Surgeons (UK) Guidelines (11). Therefore, in 82.91% of patients, the opportunity for interceptive management of impacted canine was lost. Similar audits conducted in the United Kingdom revealed that 24 – 80% of patients were referred by the age of 12 years(9, 13, 14) which was greater than the figures reported by our study. In a re-audit conducted by Hassan et al, the percentage of referrals at appropriate age improved from 16% to 27% following the introduction of guidelines (13).

The majority of the patient referrals were by General Dental Surgeons which was similar to the other audits (9, 14, 15). Only 11.36% of patients were diagnosed at the time of referral by the general dental surgeon which was significantly lower than the study by Hassan et al, which reported that 95% of cases were diagnosed by the dentist upon referral. None of the referrals evaluated in this study mentioned the findings of canine bulge palpation, which was a significant finding in our study. In contrast, the audits done in the United Kingdom reported that 25 – 32% of referrals contained information regarding the canine bulge.

The other important finding reported in this study was that only a single referring clinician had referred the patient with the appropriate radiographs. It was significantly lower than the study by Aiyegbusi et al in the UK, which reported that 40% of the referrals included appropriate radiographs (14). The lack of dental radiograph facilities in the peripheral hospitals and lack of awareness among dental surgeons regarding British Orthodontic Society Radiology Guidelines could account for this stark difference in figures.

Ninety fuve percent of patients with an impacted maxillary canine were assessed by an orthodontist within 6 months of referral to the Orthodontic unit NHK and this was comparable to the findings by Patel et al (9).

In summary, the impacted maxillary canined referrals, to the Orthodontic unit at National Hospital Kandy failed to meet the standards recommended by the Royal College of Surgeons (UK) Guidelines and British Orthodontic Society Radiology Guidelines (Table 1).

However, the authors were unable to determine or report the specific reasons for the delay(s) in referral or the stage at which the delay occurred. Potential causes could include patients presenting late, having inconsistent attendance, or showing low motivation for referral. Additionally, there may be an insufficient screening of patients aged 10 to 13 in the community, and the referring clinicians might not have been aware of the guidelines due to the absence of local protocols.

The results of this audit highlight the need for developing a local guideline for impacted maxillary canine referrals. Orthodontists and dental surgeons should collaborate with professional organizations and national authorities to formulate guidelines regarding a referral system and incorporate these guidelines into screening programmes for school children. However, previous reports have highlighted the limited impact of referral guidelines on the referral practices of general dentists for orthodontic cases. Therefore, additional methods of disseminating the information may have to be undertaken.

It is important to acknowledge the limitations of our study as well. As our clinical audit was carried out only at a single station, there is limited generalisability of results. The sample size of the study may not be enough to draw significant and reliable conclusions. Reasons for the delay in referrals were not investigated in this study; therefore the recommendations authors propose may not address the cause of these delays.

CONCLUSIONS

A considerable proportion of patients were referred late, resulting in a higher probability of needing more extensive treatment for impacted maxillary canines. This highlights the need for additional education and training for referring practitioners on the detection and management of impacted maxillary canines.

Considering the findings of this audit, the authors would like to recommend the following to be considered in developing guidelines for the management of orthodontic patients for timely and correct management of impacted canines.

- Advice the house officers and senior house officers in the orthodontic unit who are assessing the patients on the day of admission to educate the patient and parent regarding their condition on the day of admission so that they keep up with the subsequent appointments
- Create an algorithm to be followed to determine which patients require referral (Figure 7)
- Collaborate with referring practitioners to provide recommendations for improving referral patterns of impacted maxillary canines to secondary care, by sharing the audit results and organizing educational sessions for local dental practitioners and dental care professionals..
- Collaborate with professional organizations to formulate guidelines regarding a referral system.
- Incorporate these guidelines in screening programmes for school children.
- Promote professional organizations to conduct CPD programmes for dental surgeons regarding referring guidelines.

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