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Editor's Note



Dr. Rob Pasch



Dr. Kenneth Lau

Change is good. With this in mind I would like to introduce Dr. Ken Lau, who joined the editorial team earlier this year to help the editorial process in producing your journal.

Dr Lau is a well recognized general dentist with extensive orthodontic training and achievements who, in 2023, served as President of the IAO International. He has authored several articles and is very familiar with the workings of the IAO.

All in all, he is a wonderful asset to the IJO.

This issue is packed with great clinical articles and useful tips that will surely enhance your learning experience or reinforce what you already know.

Please help me welcome my friend and colleague Dr Ken Lau to his new position.

I remain
Respectfully,
Dr. Rob Pasch DDS MSc IBO General Practitioner

Evaluation of Tooth Size Discrepancy and Bolton Tooth Size Analysis in Different Angle's Malocclusion Groups:

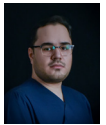
A Retrospective Study

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ABSTRACT

Background and aim: The tooth size discrepancy (TSD) is crucial in determining and predicting treatment outcomes. The Bolton analysis, which measures the mesiodistal width of the mandibular and maxillary teeth, is essential for this process. This study aims to evaluate the Bolton anterior and overall tooth size ratios and to analyze their association with various classes of dental malocclusion, as defined by Angle's classification.

Methods: In this retrospective cross-sectional study, 150 patients with complete permanent dentition and no dental anomalies were randomly selected. After excluding unsuitable casts, samples were divided into Class I, II, and III malocclusion groups. Anterior and overall Bolton ratios were measured and analyzed across groups, and gender differences were also evaluated.

Results: The present study showed that skeletal Class III patients had significantly higher anterior Bolton ratios than Class II patients. However, this difference was not statistically significant in the CLI group, although it was greater. The differences in overall Bolton ratios between different malocclusion groups were not statistically significant. Statistical analysis showed that there was a weak correlation between these parameters and anterior Bolton ratios. About 30% of patients had significant anterior tooth size differences (more than 1 standard deviation from the Bolton standard). In this study, there was no significant difference in anterior and overall Bolton ratios between the male and female groups.

Conclusion: This study revealed that skeletal Class III patients had a significantly higher anterior Bolton ratio than Class II patients. There was no significant difference in overall Bolton ratios between different malocclusion groups, and there was no significant difference in anterior and overall Bolton ratios between males and females in general.

Keywords: Bolton Analysis, Esthetics, Macrodontia, Microdontia, Tooth Size Discrepancy.

Conflict of Interest: None

INTRODUCTION

Esthetics is important in the quality of life and motivation for orthodontic treatment. Factors such as the size, proportion, and symmetry of teeth affect dental alignment, occlusion, and aesthetics.¹ Distinguishing between normal and abnormal occlusion patterns is a difficult task for dentists. The goal of orthodontics is to accurately assess and manage occlusion to achieve optimal alignment.² To achieve this, the size of the maxillary and mandibular teeth must be proportional. The tooth size discrepancy (TSD) is crucial in determining and predicting treatment outcomes. The Bolton analysis, which measures the mesiodistal width of the mandibular and maxillary teeth, is essential for this process.³ Any deviation from the patient's ideal position, in terms of size, number, shape, or dental arch, should be considered in the treatment plan before treatment begins, so that appropriate adjustments can be made during treatment to achieve a stable occlusion in the anterior and posterior areas.⁴

In 1962, Bolton discussed the clinical use of his tooth size analysis. Subsequent studies

have shown that to obtain a correct occlusion, there must be a certain relationship between the dimensions of the maxillary and mandibular teeth to achieve a tight occlusion, optimal overjet, and overbite.^{5,6} This analysis is based on a fixed ratio between the sum of the mesiodistal widths of the maxillary and mandibular teeth and is the most commonly used method for diagnosing TSDs. The ideal ratio in the anterior part of the dental arch (Bolton's anterior ratio) is approximately $77.2\% \pm 1.65$, and in the entire arch (from the first molar to the opposite molar; Bolton's Overall ratio) is approximately $91.3\% \pm 1.91$.⁷ Bolton's analysis uses two main ratios to help determine whether the teeth in the maxillary and mandibular jaws are undersized or oversized to achieve an ideal occlusion. However, the average values of these ratios differ among different populations. It is suggested to perform the Bolton analysis regularly in all orthodontic patients. Also, to save time, visual estimation of TSD at the first visit can be used as an initial screening method before detailed measurements and treatment planning.⁸ Clinical practice considers a TSD of 2 mm to be a threshold for clinical significance, and it should be taken into account in treatment planning.⁹

Multiple factors influence TSD, a sign of a mismatch between the upper and lower teeth. Various factors, such as genetic inheritance, genetic mutations, age, gender, ethnicity, dental anomalies (such as microdontia), congenital and muscular diseases, hormonal disorders, and individual behaviors can influence the occurrence of malocclusion and the formation of dental arches. The majority of tooth size variations are genetic, but environmental factors may also play a role.¹⁰⁻¹²

Different studies have been conducted to investigate the correlation between TSDs and various malocclusion groups, with some reporting statistically significant differences and others not reporting any significant differences.¹³ Malocclusions that are caused by skeletal discrepancies, especially in the anteroposterior and vertical dimensions, are one of the major challenges in the diagnosis and planning of orthodontic treatment.¹⁴ Clinicians should consider the possibility of TSDs in the diagnosis and treatment planning of orthodontic patients and implement interventions to eliminate these discrepancies during orthodontic treatment of these patients. TSDs have been studied in various types of malocclusions, but some studies have found contradictory results between types of malocclusions in the Bolton ratios.¹⁵ The differences in results between populations and sexes highlight the need for indigenous studies and studies on both sexes.¹⁶⁻¹⁸ In addition to the effect of ethnicity on tooth size, studies have shown that the degree of TSD can also differ between different types of malocclusions.¹⁸ The skeletal class can influence the buccolingual width of anterior teeth in the Iranian population, but there is no clear correlation between malocclusion classes and Bolton ratios. Studies have shown contradictory results in different malocclusion classes and the prevalence of Bolton ratio variations.¹⁹

The present study aimed to investigate the differences in tooth size and anterior and overall Bolton ratios in patients with different malocclusions and different genders, as well as the effect of the anterior Bolton ratio on the position of anterior teeth. Measurements were made on dental casts in this study to accurately assess the tooth ratios between the upper and lower jaws. The extent of TSDs was investigated through data analysis of malocclusion type and gender.

METHOD AND MATERIALS

In this retrospective cross-sectional study, approximately 400 patients were randomly selected from patient records referred to the orthodontic department of Shahed Dental School between 2020 and 2025 based on information available in the file (including age, gender, information about the dentition status, photography, panoramic radiography, and lateral cephalometric radiography). In selecting these patients, factors such as the complete eruption of all permanent teeth in the upper and lower dental arches from the first molar on one side to the first molar on the opposite side were considered. It was also confirmed based on radiographic and photographic images that the teeth were free of any specific deformity (microdontia, macrodontia) or mesiodistal/occlusal wear and interproximal caries or restorations affecting the mesiodistal width, and were free of any prosthetic treatment such as crowns. Examining the study casts that were prepared before treatment ensured that there were no bubbles, abrasions, or fractures in the teeth.

After excluding cases that did not meet the inclusion criteria, including incomplete documentation, lack of access to casts or broken casts, etc., 150 patients were finally selected for inclusion in the study. The patients were between 13 and 25 years old, and 104 were female, 46 were male. The malocclusion groups for these casts included Class I (70 patients), Class II (50 patients), and Class III (30 patients). In the three malocclusion groups, CLI, CLII, and CLIII, it was found that the Anterior Ratio and Overall Ratio were analyzed. Each group's gender effect was examined separately.

$$\text{Anterior Ratio} = \frac{(\text{Sum of M-D Mandibular Diameter (\#33 to \#43)}) \times 100}{(\text{Sum of M-D Maxillary Diameter (\#13 to \#23)})}$$

$$\text{Overall Ratio} = \frac{(\text{Sum of M-D Mandibular Diameter (\#36 to \#46)}) \times 100}{(\text{Sum of M-D Maxillary Diameter (\#16 to \#26)})}$$

To investigate the relationship between dental position and Bolton's anterior ratio, the U1-SN, IMPA, U1-PP, and interincisal angle were measured, and their correlation with the anterior ratio was also examined. The sagittal relationship of the patients was also examined in the first stage before the start of the study, according to the information available in the file, and in the next stage for certainty through cephalometric analysis based on the ANB angle. If there are any discrepancies between the data, Witt's analysis confirmation was utilized to

determine the sagittal relationship and the type of malocclusion. In class I malocclusion, the ANB angle was considered within its normal range (between 0 and 4 degrees), for class II, it was considered greater than 4 degrees, and for class III, it was considered less than 0 degrees.

Finally, the largest mesiodistal width of each tooth at the contact site was measured using a digital caliper (with an accuracy of 0.01 mm) and was used in the formula provided by Bolton to calculate its ratios. To ensure accurate results and prevent errors in the measuring instruments, the measurements were performed separately by two operators. In case of differences between the two operators, an average size was considered. The obtained data were analyzed using SPSS version 30 software.

RESULTS

The results obtained from the average calculated for the malocclusion groups based on gender are presented in Table 1 and Figures 1 and 2. The anterior and overall ratios for different malocclusions showed no difference between the two gender groups. According to the comparison of the anterior ratio in different malocclusions, the CL III group had a significantly higher anterior ratio than the CL II group ($p=0.019$). No significant differences were found when comparing the two CLI and CLII groups, as well as between CLI and CLIII. When compared, the CLIII group had the highest amount, and the CLII group had the lowest amount. The comparison of the Overall ratio in different malocclusions showed that the CLIII group had a higher Overall ratio than the CLII group, but these differences were not significant ($p>0.05$). Also, in the comparison of the two CLI and CLII groups, as well as CLI and CLIII, no significant difference was observed in the overall Bolton ratio. The results obtained from the comparison between different malocclusion groups are summarized in Table 2.

Analysis shows that there is no significant correlation between the dental parameters U1-SN, IMPA, U1-PP, and interincisal angle.

When comparing the anterior proportions obtained with the Bolton anterior proportions, the following results were obtained. In the CLI group, 31.42% of the samples had a standard deviation of more than $\pm 1SD$, and 22.85% of the samples had a standard deviation of more than $\pm 2SD$ from

Table 1

Means of Bolton ratios and distribution of samples by Skeletal Malocclusion and gender.

	Gender	Bolton Ratio	N	Mean (%) $\pm$ SD
CL I	Male	Anterior	18	78.58 $\pm$ 1.92
		Overall		91.45 $\pm$ 1.86
	Female	Anterior	52	78.40 $\pm$ 2.48
		Overall		91.52 $\pm$ 2.10
CL II	Male	Anterior	18	78.21 $\pm$ 1.45
		Overall		91.45 $\pm$ 2.20
	Female	Anterior	32	77.43 $\pm$ 1.82
		Overall		90.27 $\pm$ 1.82
CL III	Male	Anterior	10	79.24 $\pm$ 2.48
		Overall		92.68 $\pm$ 1.75
	Female	Anterior	20	79.00 $\pm$ 2.31
		Overall		91.27 $\pm$ 1.51

Figure 1

Anterior Bolton analysis for different malocclusion groups.

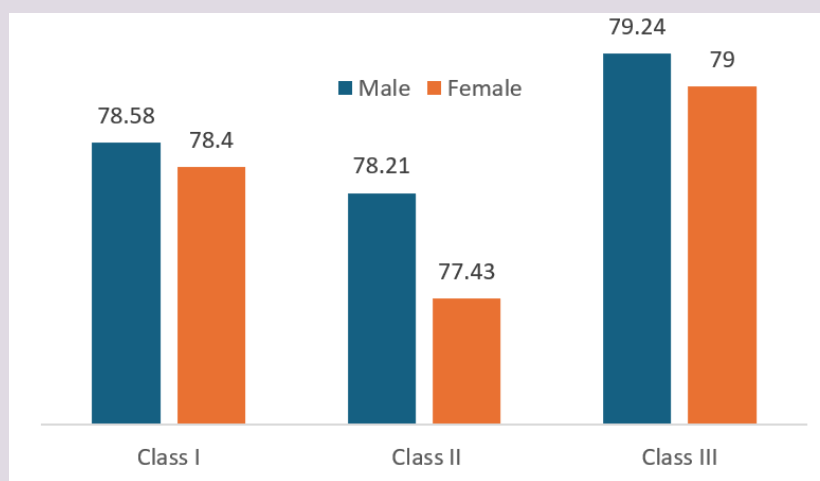


Figure 2

Overall Bolton analysis for different malocclusion groups

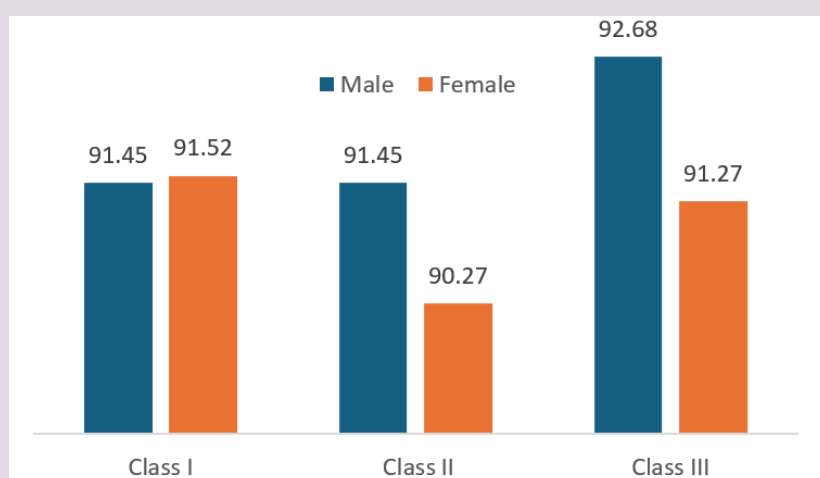


Table 2

Comparison of Anterior and Overall Bolton ratios in different malocclusion groups.

Bolton Analysis	Comparison	Mean Difference	St. Error	p-value*
Anterior Ratio	CLI-CLII	0.73	0.400	0.163
	CLI-CLIII	-0.63	0.472	0.376
	CLII-CLI	-0.73	0.400	0.163
	CLII-CLIII	-1.73	0.499	0.019
	CLIII-CLI	0.63	0.472	0.376
	CLIII-CLII	1.37	0.499	0.019
Overall Ratio	CLI-CLII	0.81	0.359	0.067
	CLI-CLIII	-0.24	0.424	0.839
	CLII-CLI	-.082	0.359	0.067
	CLII-CLIII	-1.05	0.424	0.054
	CLIII-CLI	0.24	0.424	0.839
	CLIII-CLII	1.05	0.448	0.054
* Statistically significant for $p < 0.05$				

the results obtained by Bolton. In the CLII group, 30% of the samples had a standard deviation of more than $\pm 1SD$, and 6% of the samples had a standard deviation of more than $\pm 2SD$ from the results obtained by Bolton. In the CLIII group, 23.33% of the samples had a standard deviation of more than $\pm 1SD$, and 30% of the samples had a standard deviation of more than $\pm 2SD$ from the results obtained by Bolton. In total, 29.33% of the samples had a standard deviation greater than $\pm 1SD$, and 18.66% of the samples had a standard deviation greater than $\pm 2SD$ from the results obtained by Bolton.

DISCUSSION

The prevalence of TSD in the general population has been reported to be relatively high, with 13–30% of patients having clinically significant TSD.²⁰ Other studies have also shown that 20–30% of individuals have significant anterior teeth discrepancy, and about 5–14% have Overall TSD.²¹ Accurate dimensional relationships between the maxillary and mandibular teeth are essential to ensure correct positioning and appropriate overjet and overbite. The importance of pretreatment assessment of TSD cannot be overstated.²² This study was carried out to examine the Bolton ratio of TSD among three skeletal malocclusion groups, CLI, CLII, and CLIII, and its connection to the position of anterior teeth in 150 patients, considering its significance. Due to the uneven number of patients with different malocclusions in the study population, a proportional random sampling method was used, in which 70 patients were CL I, 50 patients were CL II, and 30 patients were CL III. The study was designed to include more young patients because they require less tooth wear, proximal restorations, and prosthetic treatments. On the other hand, the higher frequency of dental problems excluded older patients from the study. Numerous studies have utilized the Angle dental classification to categorize

malocclusion groups, but it may not always match the skeletal classification. In this study, an attempt was made to match the samples in terms of dental and skeletal occlusion classification, and ultimately, the sagittal skeletal relationship was confirmed by ANB measurement and, in some cases, by Witt's analysis.

Various methods have been introduced to assess tooth size ratio; among these methods, Bolton's anterior and overall ratios are considered the most common and accepted ones. This method suggests that the anterior and total teeth should have an ideal ratio of 77.2% and 91.3% to achieve a good match between the upper and lower teeth, respectively.²³ The conventional method of measuring the difference in tooth size in this study was based on Bolton analysis ratios.

Dental casts are the most commonly used method for calculating dental ratios in Bolton analysis.²⁴ Bolton Analysis measurements based on CBCT and intraoral scans or indirect scans (scans of study casts) provide acceptable results and have been recommended as an alternative to plaster casts, but their use may be limited due to radiation exposure, higher costs, and the need for a trained operator and additional equipment.²⁵⁻²⁸ Intraoral images can be used to calculate Bolton ratios with high accuracy and reproducibility, and they are recommended as an alternative for large-scale studies with large sample sizes.²⁹ Study casts are a key tool in the diagnosis and planning of orthodontic treatment, as they allow for the three-dimensional recording of the initial state of malocclusion, the course of treatment, and the final results.³⁰ However, it has been reported that the use of digital calipers for measurements on plaster models has the highest accuracy and repeatability compared to other measurement methods.³¹ The traditional method of measuring with digital calipers on dental casts was used in this study to determine Bolton ratios.

In this study, there was no significant difference in the anterior and overall Bolton ratios between males and females, which is consistent with the results of other studies.^{24,32} Also, there was no significant difference in the Bolton ratio between the three malocclusion groups according to gender. Although the male group had higher average ratios than the female group, there were no significant differences between them. In the systematic review conducted in 2020 by Machado et al., it was confirmed that gender has almost no effect on the mesiodistal ratio of teeth.³³ Another study also emphasized the absence of differences in gender groups, especially in the overall Bolton ratio in different malocclusion groups.³⁴ However, some other studies have shown the opposite; for example, Smith et al. concluded that demographic and gender groups can have a significant effect on intermaxillary tooth size ratios.³⁵ Also, in a study on the Turkish population, Uysal and Sari reported that the overall Bolton ratios were significantly larger in men than in women.³⁶ However, these gender differences were small in both studies, less than 2%.

The average Bolton ratio for the 150 samples was 47.78 (compared to a Bolton ratio of 2.77), and the overall ratio was 44.91 (compared to a Bolton ratio of 3.91). Group CLIII had a significantly higher anterior ratio than group CLII in the three malocclusion groups, but this difference with group CLI was not statistically significant. In terms of the mean anterior Bolton ratio, the three groups were CLII < CLI < CLIII, respectively. In the case of the Overall ratio, the malocclusion group CLIII had a greater difference with group CLII, and this difference with group CLI was less; however, this difference was not significant. Overall, group CLIII had the highest percentage (30%) of anterior standard deviations greater than $\pm 1SD$ from the Bolton ratio. A study in 2020 showed that there were statistically significant differences in the overall and anterior tooth size ratios between different malocclusion groups.³⁷ However, another study rejected this hypothesis.³⁸ On the other hand, many researchers have not observed any significant differences in their studies.¹³ The findings of this study, that the anterior Bolton ratio is higher in Class III patients, were also confirmed in the study of Aktürk et al. conducted in 2022,¹⁵ and also in the study of Guarnieri et al. in 2025.²⁰ In the study of Roy et al. in 2025, which aimed to determine Bolton ratios in a group of orthodontic patients, it was found that in Class I and Class III malocclusion, the mesiodistal width of the teeth in the anterior part of the mandible was greater than its normal range and increased. Also, in Class II patients, there was an increase in the anterior tooth mass of the maxilla.³⁹ In a 2016 study by Hanna & Ellis, it was found that in Class II patients requiring mandibular advancement, differences in anterior Bolton ratios could also prevent the achievement of a Class I occlusion. In addition, it was recommended that, if necessary, the width of the lower anterior teeth should be reduced or a space should be created distal to the maxillary lateral

anterior teeth to allow for a firm Class I occlusion for the canine at the time of surgery.⁴⁰ Another study showed that in the normal occlusion group, the anterior and overall ratios were larger than the values in the original Bolton study.⁴¹ Another study also found that the mean anterior Bolton ratio in subjects with normal occlusion was larger than the original Bolton ratio.⁶

Studies have shown that racial background can affect TSD.⁴² One way to influence Bolton ratios is through changes in tooth shape or size.⁴³ For example, a systematic review by Wang et al. (2021) found that gender and ethnicity were identified as factors affecting the size of maxillary anterior incisors.⁴⁴ This difference in tooth size may be related to differences in race and ethnicity. Several studies have also supported the hypothesis that there are significant differences between racial and ethnic groups. In a study by Abd Rahman et al. (2023), a significant difference was observed between the TSD of the three main ethnicities (Chinese, Indian, and Malay) in Malay patients, Chinese patients, and Indian patients in Malaysia. Bolton standards can be applied to Chinese and Malaysian Indians, but do not apply to Malay orthodontic populations for both anterior and overall ratios.¹⁷ A 2023 study by Awawdeh et al. in a Saudi Arabian population showed that the majority of the studied samples had overall and anterior Bolton ratios that differed from the norms of Bolton standards and tended to increase anterior and overall ratios.⁴⁵ Another study in a Saudi Arabian population by Omar et al. in 2018 showed that males generally had larger dental arch sizes than females, and the prevalence of tooth size differences in anterior Bolton ratios was higher than in overall ratios.³² Also, in a study by Hussein et al. in 2022, it was found that the tooth size ratios of Egyptian orthodontic patients generally differed from the original Bolton standards. Patients with class I and class III malocclusion had larger anterior and overall ratios than patients with class II malocclusion, and there was no significant gender difference in any of the ratios.⁴⁶ In a study conducted in a Nepalese population, no significant differences were observed in anterior and overall Bolton ratios when these ratios were compared based on malocclusion classes or patient sex. Clinically significant anterior TSDs were more common than the Overall ratio.⁴⁷ A 2018 study by Ajami et al., conducted in an Iranian population, also showed that in the sample group, 34.7% of the anterior Bolton index and 20.7% of the overall Bolton index had an anterior Bolton index greater than 2 standard deviations (2SD) from the Bolton mean.⁸

Another reason why the difference in the Bolton ratio between dental proportions in each individual, especially in the anterior ratio, can be caused by changes in dental parameters such as inclination, tipping, and rotation. The anterior ratio was correlated with dental parameters U1-SN, U1-PP, IMA, and interincisal angle, as investigated in this study. The statistical analysis revealed a weak correlation between these parameters and the

Bolton anterior ratio. However, in one study, the anterior Bolton index was shown to be correlated with several skeletal parameters.¹⁴ It has also been proven that the vertical growth pattern affects the Bolton ratio and the prevalence of malocclusions in combination with sagittal malocclusions.⁴⁵ Another study concluded that analysis of the inclination of all the teeth of both arches in Class III malocclusions, compared with conventional standards, showed a compensation for the maxillary posterior teeth, with a decrease in palatal inclination and an increase in lingual inclination in the mandibular anterior teeth.⁴⁸ However, these results are contradictory, and in another study, no relationship was found between the anterior teeth variables and the maxillary-mandibular relationship and dental crowding.⁴⁹ The discrepancy between previous studies and the data of the present study may be due to the study's limitations in measuring only angles and using cephalometric indices. Part of the compensation that occurs to cover the difference in Bolton ratios occurs as rotation or crowding, which can occur without changing the anteroposterior angle of the teeth.

CONCLUSION

This study revealed that skeletal Class III patients had a significantly higher anterior Bolton ratio than Class II patients. The statistical significance of Bolton ratios between different malocclusion groups was not significant overall. The Bolton ratios did not reveal any significant gender differences.

Despite the weak correlation between the anterior Bolton ratio and anterior tooth angular parameters, TSD assessment is still essential in initial orthodontic evaluations. By knowing the discrepancy, the orthodontist can better anticipate treatment outcomes and perform treatments like composite build-up or mesiodistal tooth tissue harvesting.

Localized research and population-based criteria are needed to address the differences in study results across populations and ethnic groups. Studies with more rigorous methodologies and three-dimensional assessments are recommended as a result of the conflicting results in the literature.

ETHICAL APPROVAL

This retrospective study was conducted using previously prepared patient records and study casts, without any additional procedures.

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Space Closure vs. Space Opening: Solving Diastema in Hypodontia

A CASE REPORT

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ABSTRACT

This case report presents a multidisciplinary approach in treatment planning for a patient with hypodontia and spacing. The patient's chief complaint was multiple diastema on both anterior and posterior regions, unfavorable smile and sensitivity of the lower front teeth. Having had braces for seven (7) years, with a constant opening up of spaces or relapse, the patient requested for an esthetic and restorative solution. A comprehensive diagnostic evaluation confirmed hypodontia, resulting in generalized spacing across the maxillary and mandibular arches.

To address the malocclusion and restore optimal dental and skeletal balance, a combination of functional and fixed orthodontic appliances was employed. Treatment objectives focused on correcting the asymmetric molar relationship, managing the effects of hypodontia, improving incisor angulation, and resolving the deep bite, creation of appropriate spaces for prosthetic replacement of missing teeth and esthetic rehabilitation of lower anterior teeth with attrition. Additional goals focused on improving vertical dimension, mandibular position based on phonetics and functions and achieving stability to manage bruxism.

Keywords: hypodontia, multiple diastema, attrition, bruxism, deep bite, vertical dimension, ortho-esthetics

Conflict of Interest: None

INTRODUCTION

Dentistry is now taking its higher level of services that go beyond what eyes can see. We are surpassing the level of beauty but going deeper into what the body feels and how our treatment affects wellness. This case presentation is grounded in the dual demand of patients to look beautiful and remain pain-free, which requires a treatment philosophy that begins with aesthetics and culminates in biological health.

Hypodontia or dental agenesis or congenitally missing teeth (CMT) is one of the most common dental developmental anomalies. Accordingly, the developmental absence of one or more teeth excluding the third molar teeth is defined as "hypodontia". Some other researchers suggested that the absence of one to six teeth should be called "hypodontia", and the absence of more than six teeth should be called "oligodontia."¹ Hypodontia can compromise both dental function and esthetics. Individuals with missing teeth often face challenges such as malocclusion, limited alveolar bone development, impaired mastication, reduced chewing efficiency, speech articulation difficulties, periodontal complications, and esthetic concerns linked to altered skeletal relationships and unfavorable appearance. These consequences may diminish self-esteem, affect communication patterns, hinder professional performance, and ultimately reduce overall quality of life-frequently requiring a multidisciplinary approach to treatment.²

Using a facially generated treatment planning system, the process starts by asking where the teeth should be positioned to achieve optimal dentofacial aesthetics.³ Once the aesthetic goals are defined, attention shifts to function, examining how the oral structures move and ensuring that occlusion and mandibular dynamics support both beauty and comfort. From there, the impact of function on development is considered, particularly in relation to the temporomandibular joint and airway, as these structures are critical to long-term stability.

Finally, the plan focuses on biology and physiology, creating and recreating the natural health of the oral cavity so that the outcome is not only esthetically pleasing but also biologically sound, structurally stable, and functionally sustainable. In this way, the systematic method integrates esthetics, function, structure, growth, and biology into a logical, interdisciplinary framework that ensures patients achieve both beauty and pain-free oral health.⁴

“Where the teeth go defines esthetics, what they do ensures function, when we treat aligns with growth, and how we finish preserves biology.”

CASE PRESENTATION:

Patient Information: A 25-year-old Filipino male patient came to the clinic, with the following chief complaint: “I have multiple gaps on my teeth and it does not look good. My teeth are wearing out and I can feel some sensitivity. I hope you can restore it for me.”

Medical History: The patient reports no significant medical history relevant to dental treatment.

Dental History: The patient underwent orthodontic treatment during late adolescence (4 years in High School) and again into early adulthood (3 years), encompassing both active growth and post-growth stabilization stages.

Framework theme: balancing beauty and comfort-optimized outcomes in dentofacial treatment planning:

Step 1: Esthetics – Where do I want the teeth to go to create better dentofacial esthetics?

Intra-Oral Photos

Figure 1.

Analysis of facial proportions, smile line and tooth positioning; (a) Frontal to lips is closed, with a symmetrical mesocephalic facial type; (b) Gingival display is deficient corresponding to a low smile line (c) Profile is straight with a competent lip posture. Nasolabial angle is within aesthetic limits, while the mentolabial sulcus appears strained and the chin is large.



Figure 2.

Macroesthetic Analysis and Measurement of Horizontal and Vertical Symmetry; (a) Interalar line is longer than ophratic line, Lower third of the Face is 1.5mm longer than interalar line; (b) The distance between the eyebrow and the chin is slightly longer than the width of the face. Measurement shows a normal lower facial third of the face; (c) Horizontal symmetry is normal; (d) Vertical symmetry shows a slight deviation on the center of the nose; slightly to the right.



Figure 3.

Facial profile and Cephalometric Analysis; (a) Facial profile is straight. The chin is slightly dish-in; (b) Soft tissue analysis shows that the patient has retruded upper and lower lips. The patient exhibits a normal lip seal. The nasolabial angle measures 84°, which is slightly less open than ideal range for males (90-95°).

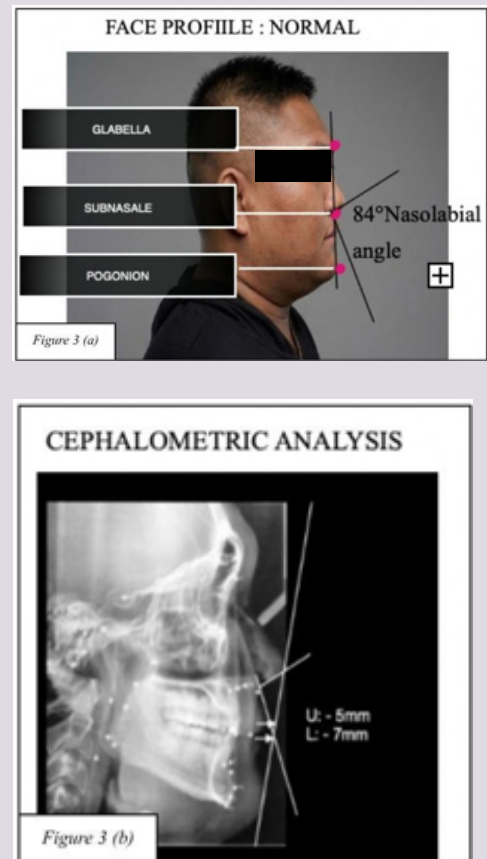


Figure 4.

Tooth Position Analysis based on Intra-oral Photos (a) The right side demonstrates a Class 1 occlusion whereas the left presents a Class II occlusion, indicating asymmetry in the occlusal pattern. (b) Hypodontia of lateral incisors has resulted in mesial drift of the canines (#13 and #23) which migrated into the lateral spaces, thereby establishing a bilateral Class II dental relationship. (c) Both upper and lower incisors are retroclined, accompanied by a 5mm deep bite and evident incisal attrition. (d) Tooth color is within normal limits, with slight decalcification noted. (e) The upper labial frenum exhibits low attachment. (f) Arch spacing is measured at 5.5 mm in maxillary arch and 9mm in the mandibular arch.

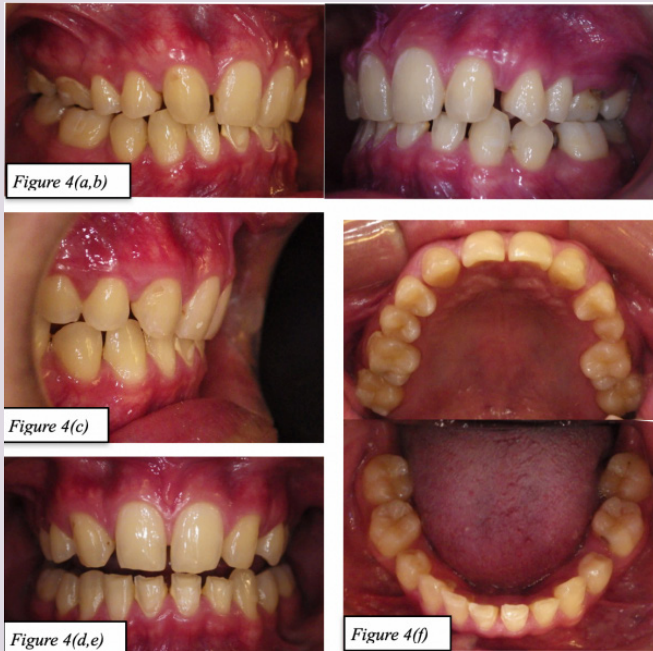


Figure 5.

Functional and Structural Analysis of Tooth Position based on panoramic radiograph. Establish esthetic goals before functional or structural considerations. The patient presents with eight missing teeth: seven congenitally absent (#12, #22, #45, #18, #28, #38, #48) and one extracted (#35).



Figure 6.

Facially Generated Smile Design. Establish esthetic goals before functional or structural considerations. Use digital smile design or facially generated planning tools. Extra-oral photograph reveals absence of posterior tooth display, presence of a black triangle and incisal edges not resting on the vermillion border of the lip.



Step 2: Function – How does the structure of the oral cavity move?

Evaluate occlusion, mandibular dynamics, and chewing patterns. Ensure functional harmony between teeth, muscles and joints. Consider how esthetics positioning impacts functional movement.

Figure 7.

Figure 7 (a). Cephalometric Analysis. Cephalometric reveals the skeletal classification of Class I based on Steiner's Analysis for SNA (80°) and SNB (79°) with ANB result of 1° and Class III based on wits of -3mm. The patient exhibits a significant mandibular length excess (Co-Gn=124mm vs. Co-A=91mm), with a difference of 33mm indicating a sagittal skeletal discrepancy (Al-Ani et al., 2017). Proper diagnosis and treatment planning in this case with a confusing skeletal and dental classification plays a major role in the success of the treatment. A clear understanding of the causes of the variations of classifications are as follows: Class I based on Steiner's Analysis for SNA (80°) and SNB (79°) with ANB result of 1°. This may be attributed to cranial base morphology, posterior positioning of Point A. Based on growth and development, the first body parts that grow are the ones nearer the brain, so the cranial base grows bigger first before the maxilla. Based on embryological development, the anterior teeth (tooth buds) begin to form before the mandible has fully developed. So, due to compensations like retroclined incisors, the ramus of the mandible grew horizontally. So, it can be concluded that the final skeletal classification of the patient is Class III.

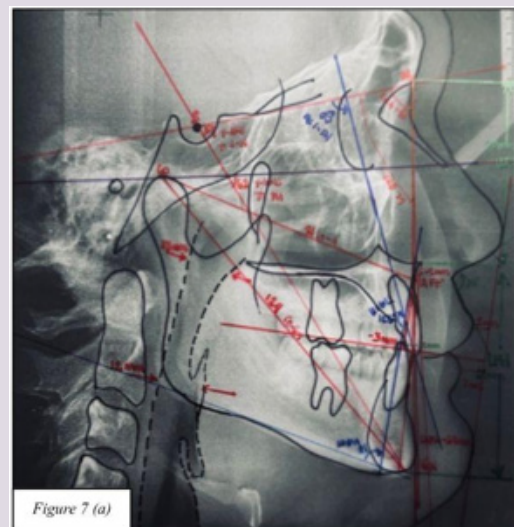


Figure 7.

Figure 7 (b). Occlusion and Mandibular Movement Analysis. (a) Dental attrition is the wearing of the incisal or occlusal surfaces of teeth as a result of functional or parafunctional tooth-to-tooth contact. Regular attrition is slow tooth wear associated with chewing. Sleep disorders like bruxism cause more significant tooth wear.⁵

The cephalometric values of patients with congenitally missing teeth show a significant difference in anteroposterior dimensions compared to the norms. It is observed that jaws are in a slightly posterior position in patients with hypodontia. Therefore, patients with missing teeth have decreased vertical facial dimensions with a flat and retrognathic profile in general. Upper and lower incisor teeth are significantly more retroclined.

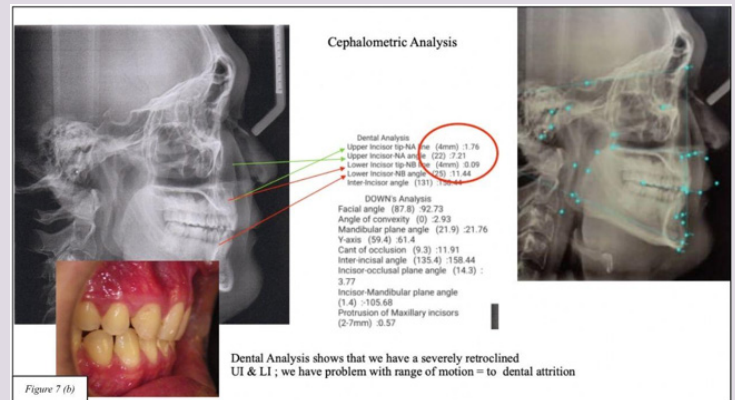


Figure 8.

Gnathological Analysis. (a) Effects of Hypodontia Condyle is slightly on posterior position;⁶ Upper and lower anterior teeth are retroclined; Increased in interincisal angle: 158.44 (mean: 135.4) deep bite; Have abnormal contoured crown; Decrease in the lower facial height: 61.45 (S-60-62).

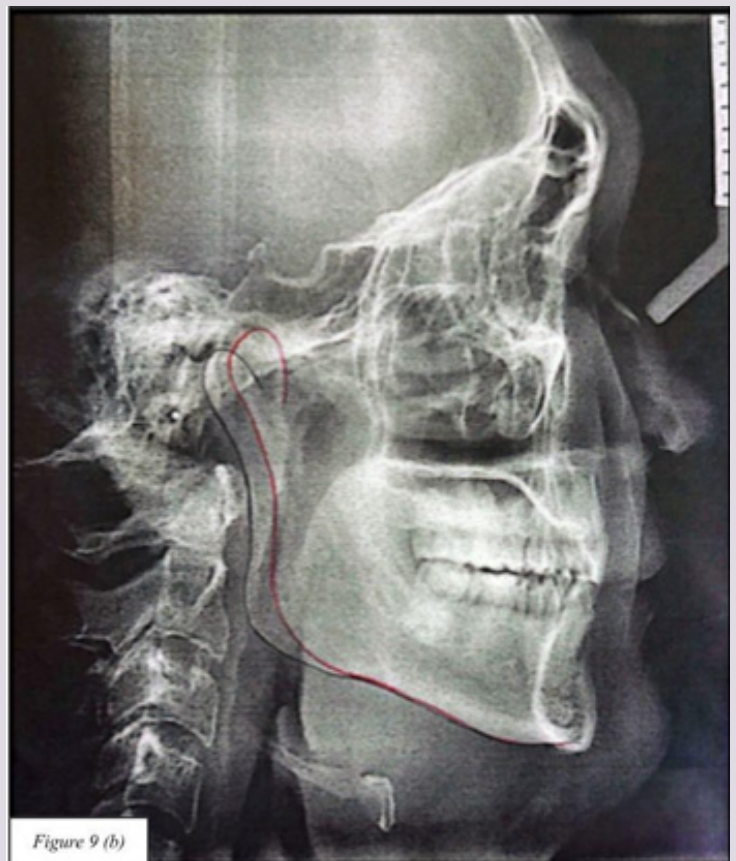


Step 3: Structure and Development: What is the effect of function on development (TMJ and Airway)?

Assess Temporomandibular joint health. Evaluate airway dimensions and breathing patterns. Identify risks of dysfunction (e.g., malocclusion leading to TMJ stress).

Figure 9.

Temporomandibular Joint & Airway Analysis. (a) The right condyle appears slightly anteriorly positioned within the glenoid fossa, while the left condyle exhibits less anterior translation, sitting more posterior superior.⁷ Both joint space symmetry and cortical integrity are maintained. The patient does not feel any TMJ disorder amidst the bruxism habit. (b) Functional Evaluation. The patient demonstrates a maximum mandibular opening of 49 mm, which is within normal functional range. Restricted lateral excursions are a result of a deep bite and retroclined anterior teeth, probably because there is less anterior guidance. Temporomandibular joint (TMJ) function is asymptomatic despite parafunctional behaviors; no joint noises, pain, or movement restrictions have been noted. The patient can swallow with their lips closed. Evaluation of the muscles and soft tissues shows no anomalies. However, occlusal interferences may be a cause of sleep problems. Though the patient has a normal range of airway (13mm on nasopharynx and 12mm on oropharynx), it is still on the lower end of normal on a typical range of airway dimension for adults (15-20mm nasopharynx and 14-20mm on oropharynx).



Step 4: Growth and Timing: When to start and finish the case?

Consider the patient's age and growth stage. Align treatment with developmental milestones. Plan interventions to maximize long term stability.

The patient underwent orthodontic treatment for approximately seven years, beginning in Grade 9 and during college. Post-debanding, no diastemas were initially observed; however, tooth spacing gradually reappeared over time, which he attributed to non-compliance with retainer wear.

Upon comprehensive evaluation, it was determined that opening the spaces for four congenitally missing teeth (hypodontia) - rather than retracting the existing dentition - would provide a more balanced solution in harmony with his maxillary and mandibular skeletal framework.

Prior to orthodontic treatment, deep scaling and root planing were performed to manage his Stage I periodontal condition. Restoration of all carious lesions was also completed to ensure optimal oral health before initiating orthodontic intervention. The patient does not feel any TMJ pain. Despite the deep bite, the condyle sits close to the articular eminence, not deep in the fossa. Immediate correction of bite morphology is necessary to stop the patient's parafunctional habit of bruxism. Increasing the vertical height to give way for the improvement of the inclination of anteriors must be done prior to the esthetic rehabilitation of the lower anterior teeth with attrition.

Once the anterior guidance is established, closing spaces with prosthesis and recontouring of premolar with microdontia will be done.⁸

Step 5: Biology and Physiology: What to create and recreate?

Restore biological health of teeth, periodontium, and oral tissues. Recreate natural physiology for sustainable outcomes. Ensure treatment supports long-term oral health, not just esthetics.

Problem List

1. Medical and Dental findings of significance:

- No known medical condition that will affect the treatment
- Flat, retrognathic and dished-in facial profile
- Decreased facial height
- Strain of the mentalis muscle
- Hypodontia of two upper laterals and two 2nd premolars
- Microdontia of tooth #25
- Multiple spacing, deep bite
- Retroclined upper and lower incisors

2. Alignment:

- Maxillary Arch - orthodontic space opening is possible. Crossbite molars show transverse asymmetry
- Mandibular Arch - multiple spaces are observed. Incisors are with attritions. Lower anteriors are retroclined. Bolton discrepancy (mandibular excess of 7.05)

3. Vertical:

- Skeletal: Low vertical thirds
- Dental: No incisor shown at rest; 75% deep bite

4. Anteroposterior:

- Skeletal: Class III profile based on Co-GN and Co-A wits.
- Retruded mandible and normal maxilla.
- *Dental: 0 overjet, 75% deep bite
- 5. Transverse:
- Skeletal - None
- Dental - crossbite on posteriors

Figure 10.

a) Treatment Plan Analysis. The anterior ratio of 109.365 is higher than the ideal (77.2%). It means that the lower anterior teeth are disproportionately larger (7.05mm) compared to the upper anterior teeth. Since the maxillary laterals are missing, space opening and replacement of the laterals are required to balance the tooth size discrepancy and achieve a proper occlusion and esthetics.

MESIAL-DISTAL WIDTH		
TOTALS	UPPER	LOWER
5 - 5	62.81	53.31
6 - 6	-	-
3 - 3	34.7	37.95
ARCH LENGTH DISCREPANCY (ALD)		
MAXILLA	MANDIBLE	
4.39	6.06	
TOTAL ALD - CURVE OF SPEE		
MAXILLA	MANDIBLE	
4.39	3.56	
BOLTON'S ANALYSIS		
ANTERIOR RATIO	TOTAL RATIO	
109.36599	-	
TOTAL RATIO	EXCESS	
L6 - 6	-	
U6 - 6	-	
ANTERIOR RATIO	EXCESS	
L3 - 3	7.05	
U3 - 3	0	

Figure 10 (a)

Figure 10 (a)

- **Purpose:** Evaluates the tooth size discrepancy between the maxillary and mandibular teeth.
- **Method:** Uses specific ratios (overall and anterior) to determine if there is excess or deficiency in tooth material.
- **Clinical Use:** Helps in treatment planning - especially for spacing, crowding, and achieving ideal occlusion.
- **Formula Example:** Overall Ratio = (Sum of mandibular 12 teeth / Sum of maxillary 12 teeth) × 100
- **Anterior Ratio**⁹ = (Sum of mandibular 6 anterior teeth / Sum of maxillary 6 anterior teeth) × 100

Orthodontic Space Opening thru Fixed Appliance

Treatment Goal:

1. Create an ideal sized area for the replacement of missing teeth
2. Ensured adequate root parallelism
3. Improved sagittal and vertical dimensions
4. Correct deep bite
5. Create a decent overjet
6. Improve range of motion
7. Improve condyle position
8. Improve interincisal angle

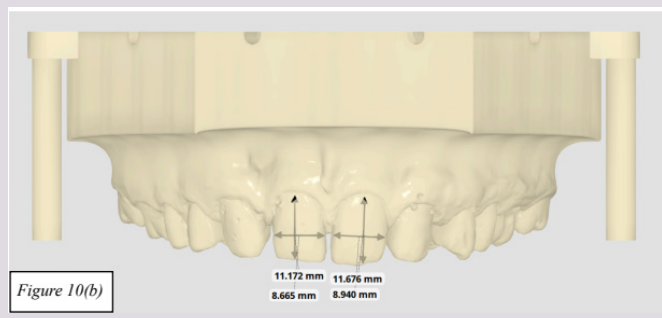
Esthetic and Prosthetic Restorative Treatments

Treatment Goal:

1. Options are resin bonded fixed partial prosthetic restorations, conventional fixed partial prosthetic restorations, implant supported prosthetic restorations or modified adhesive partial prosthetic restorations
2. Restoration of attrition of lower anteriors with the ff options: crowns, dental bonding or veneers
3. Restoration of abnormal contoured crown with the ff options: crown or dental bonding

Figure 10b.

Mesiodistal Width of the patient's Central Incisors



Orthodontic Space Opening through Fixed Appliance

Ways to determine the proper space for missing lateral incisors:

1. Golden Ratio (1.618:1)¹⁰

- Based on a mathematical constant found in nature, art, and architecture.
- In dentistry, it suggests that the visible width of the lateral incisor should be 62% of the central incisor, and the canine should be 62% of the lateral incisor.
- Often used in smile design to create visually pleasing proportions.

Example Computation:

Size of CI = 8.66 / 8.94

Round off is 9mm

Step 1:

Lateral = 9mm x 0.618mm = 5.562mm

Step 2:

9mm x 0.382mm = 3.438mm

Figure 10c.

Golden Ratio Summary Table

Tooth Width (mm) ratio to central	Ratio to	Central
Central Incisor	8.5	1.000
Lateral Incisor	5.26	0.618
Canine	3.25	0.382

2. Esthetic Space Planning:¹¹

- Apply Dr. Stephen Chu's tooth proportion guidelines to determine ideal mesiodistal widths for prosthetic replacement.

$$CI = Y(X+3) / 6 + 3 = 9$$

$$LI = Y(-2) / 9 - 2 = 7\text{mm (ideal size for each upper lateral incisor)}$$

-4.39mm (current space available)

=2.61mm (space required for each side)

*Therefore, an additional 5.22mm of space is required to accommodate ideal prosthetic replacement of the two missing lateral incisors.

Mechano-therapy

1. Appliance Placement

- Direct bonding of fixed straight wire appliance (Roth 0.022 slot) on all permanent teeth
- Cementation of first molar bands
- Bonding of second molar buccal tubes for transverse guidance

2. Vertical Dimension Correction

- Placement of calibrated 1.5mm custom-shaped composite (myolay) on teeth #46 and #36 on lower 1st molars to encourage the retrusive lower jaw to move slightly forward to relax the muscle and TMJ strain. As well as to avoid lower brackets' dislodgment during occlusion.
- Create an ideal overbite (5mm deep bite -2.37 open bite =2.63 mm created overbite)
- Target Shimbashi correction from 14.20 mm to 17 mm which is equivalent to 2.8mm increase in vertical dimension
- Key considerations: mandibular repositioning, occlusal stability, and neuromuscular adaptation

3. Initial Alignment Phase (Fig. 11b)

- Insertion of CuNiTi 0.014 archwires in both arches

- Progression to CuNiTi 0.016 at next adjustment
- Goal: gentle leveling, arch form development, and bracket slot engagement

4. Space Creation & Anterior Protraction (Fig. 11c)

- NiTi coil springs placed on 0.016 NiTi wire:
 - Upper arch: between central incisors (#11/#21) and canines (#13/#23)
 - Lower arch: between canines (#33/#43) and lateral incisors (#32/#42)
- Activated monthly for 3 months
- Purpose: improve anterior inclination and initiate space closure

Figure 11a.

Vertical Dimension Correction. Geometry of Bite Opening¹²
 Posterior Build-Up x $\frac{\text{Condyle Incisor Distance (Go-Co)}}{\text{Condyle Molar Distance (Condyle-incisor distance)}}$

Ratio = $98.81 = 1.58\text{mm}$

62.61 Therefore $1\text{mm myolay} = 1.58\text{ anterior open bite}$

$\frac{1.58}{2} = 0.79 + 1.58 = 2.37\text{ open bite can be achieved with } 1.5\text{ mm of myolay } (.5\text{mm})$

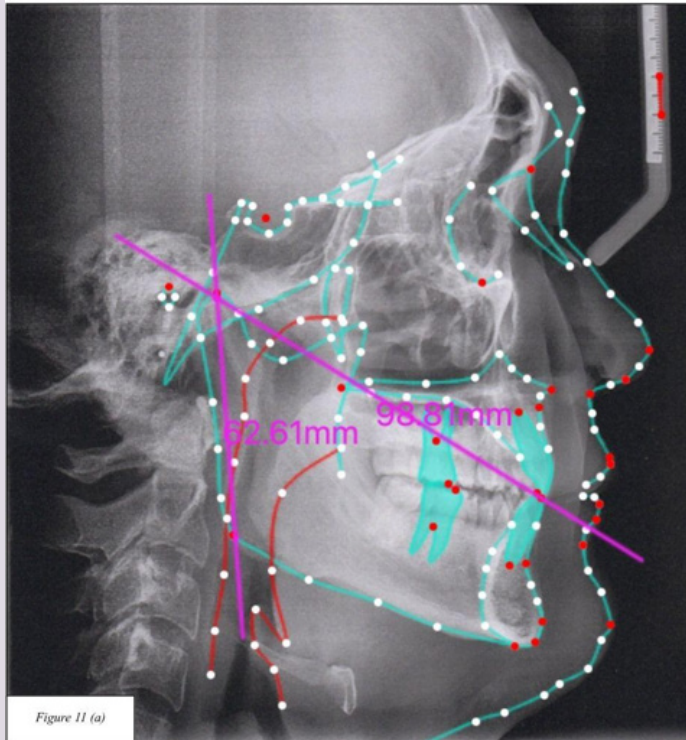


Figure 11b.

Space Creation & Anterior Protraction.



Figure 11 (d). Targeted Space Creation

5. Anchorage Control & Slot Engagement (Figs. 12.1a-12.1c)

- Synch-back bends placed distal to second molars
- Heat-treated wire ends for controlled bending without slot compromise

6. Targeted Space Creation

- Lower coil spring repositioned between first premolars (#34/#44) and canines (#33/#43)

Figure 11c.

Anchorage Control & Slot Engagement



Figure 11d.

Targeted Space Creation



Figure 11e.

Upper Lateral Space Management



- Objective: create 7 mm space for missing lower premolar
- Lower anteriors laced with 0.020 SS wire to resist unwanted movement

Figure 11 (e). Upper Lateral Space Management

7. Upper Lateral Space Management

- 7 mm space needed for upper lateral incisors (#12/#22)
- Achieved via monthly coil spring activation over 12 months

Figure 11f.

Transverse Expansion



8. Transverse Expansion

- Guided by second molar buccal tubes
- Supported by proper tongue posture, with maximum isometric tongue force 52.1 Newtons (N) or 5.31 kilograms.¹³
- Goal: arch width enhancement and additional space creation

9. Controlled Retraction & Interdigitation

- T-loop mechanics on upper arch using 0.019 × 0.025 SS wire
- Activated with synch-back bends
- Box elastics on left and right posterior teeth using 3/16", 6.5 oz elastics
- Purpose: achieve proper interdigitation and posterior settling

10. Finishing Stage

- Use of Beta Titanium (TMA) wires
- Precision wire bending for final detailing and torque control

11. Final Ligature Technique

- Figure-of-8 ligature using 0.007 SS wire, spanning end-to-end
- Duration: 2 months
- Purpose: stabilization and final arch coordination

12. Estimated Treatment Duration

22 months total

Figure 12.1

Anchorage Control & Slot Engagement

12.1a. Pontic for laterals and premolars were installed after achieving the desired space needed. Synch-back bends placed distal to second molars. Heat-treated wire ends for controlled bending without slot compromise. Stainless steel ligature wires used instead of elastomers to ensure full slot engagement, prevent tipping and wire distortion, minimize wire play during coil spring activation.



12.1b. Class II elastics on left and right posterior teeth using 1/4", 6.5 oz elastics.



12.1c. For stabilization and final arch synchronization, a figure of 8 ligature wire made of 0.007 stainless steel wire was spanned end to end for two months.



It is anticipated that correcting mandibular position to appropriate centric relation will significantly reduce bruxism, enhance joint comfort, reduce restorative wear and improve the quality of sleep. Establishing sufficient interdigitation and posterior settling is the aim. The patient's awareness of tongue posture will be crucial for maintaining an open airway and promoting orofacial muscle adaptation. Continued encouragement during follow-ups will help sustain this behavior.

Figure 12.2

Esthetic Restorative Treatment

12.2a. Phase 1 Orthodontic Treatment using fixed appliance created the desired spaces needed for the missing laterals (Teeth #12 & #22) and premolars (Teeth #44 & #34) and enough space to restore the natural height of lower anteriors.



12.2b. Immediately after gaining the space necessary to restore the teeth to their natural height, lower brackets were removed. Cement removal, cleaning and polishing of teeth were done in preparation for restoration.



12.2c. Shade selection was done based on the color of the opposing teeth. Shade A3 for the body. Shade A3.5 for the cervical and Incisal Shade for the incisal edge.



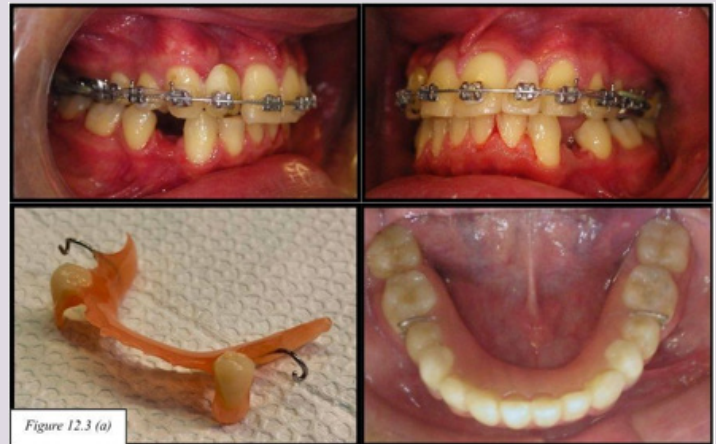
12.2d. Direct Composite Restoration.

- Removal of lower brackets after achieving the desired space for restoration of anterior teeth with attrition
- Direct composite veneers were placed on the mandibular anterior teeth, restoring crown height from 7mm to 9mm.



Figure 12.3

12.3a. Prosthodontic Treatment



Interim Removable partial denture with modified clasps

After establishing the anterior guidance, the next step is to close the space created for the lower premolars.¹⁴ An interim removable partial denture can serve as prosthesis until the patient decides to proceed with implant placement.

A removable partial denture with modified clasps was fabricated to serve as:¹⁵

- **SPACE MAINTENANCE** - preserves the created space until definitive implant therapy is undertaken.
- **PREVENTION OF RELAPSE** - to minimize the possibility of mesial drift or physiological movement of the teeth to the edentulous space.
- **SUPPORT FOR OCCLUSAL FUNCTION** - assists the masticatory muscles in proper occlusion.
- **IMPROVED ESTHETICS** - enhances the patient's appearance and patient confidence by placing the triangular clasps in between 1st molar and premolar; areas that are not visible when smiling and talking.
- **AIDS IN MASTICATION** - restores chewing efficiency, thereby improving dietary function.
- **SPEECH IMPROVEMENT** - contributes to clearer pronunciation and articulation.

In restorative dentistry, occlusion plays a pivotal role in the success of any prosthetic treatment, whether it involves a tooth surface restoration, a crown, a tooth or implant-supported prosthesis, or a tissue-supported prosthesis. A harmonious occlusal relationship will ensure stability, comfort, and function; inadequate occlusion can result in numerous complications like pain or discomfort, tooth mobility, progressive tooth wear, fractured teeth or restorations, and TMJ dysfunction.¹⁶

12.3b. With this in mind, malformed tooth #25 was restored with



12.3c. Implants are the best treatment option to replace the missing laterals and premolars. However, due to the patient's financial constraint and psychological consideration, Maryland bridge serves as the next best alternative, functioning as an interim prosthesis.



Figure 12.3(C)

Figure 13.1

Intra-Oral photos of treatment outcomes

13.1a. Lateral Incisor Space of 7mm on both arches was achieved. Maryland Bridge made of ceramag was installed as prosthesis for the missing laterals.



Figure 13.1 (a)

13.1b. Direct composite veneers were placed on the mandibular anterior teeth, restoring crown height from 7mm to 9mm.



Figure 13.1 (b)

13.1c. From Left-side Class II molar and bilateral Class II canine relationships to Class I molar and canine relationship.



Figure 13.1 (c)

13.1d. Deep bite, now fully resolved. Posterior crossbite involving maxillary first molars (#16 and #26), corrected to restore transverse arch coordination.



Figure 13.1 (d)

Figure 13.2

Congenitally missing teeth, restored to achieve functional and esthetic completeness. Tooth #25, presented with microdontia, was restored with a porcelain-fused-to-tilite crown.



Figure 13.2

Figure 14

Outcome achieved in the space gained for the upper laterals and in the restoration of lower incisors with attrition.

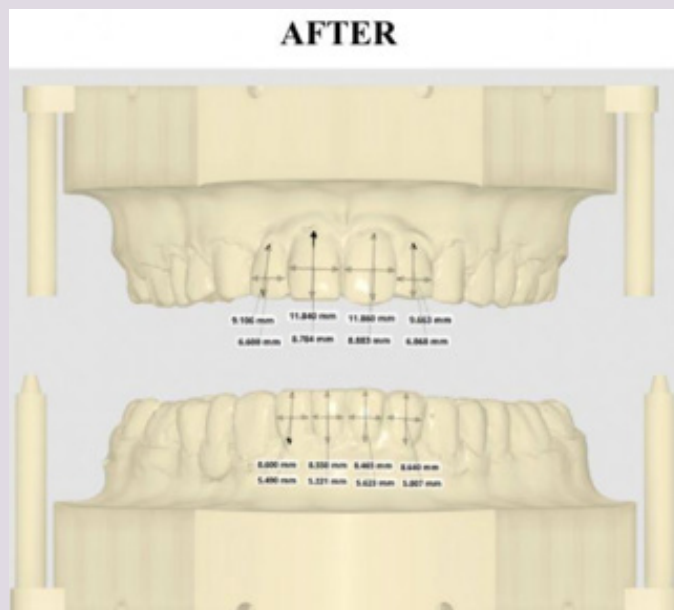
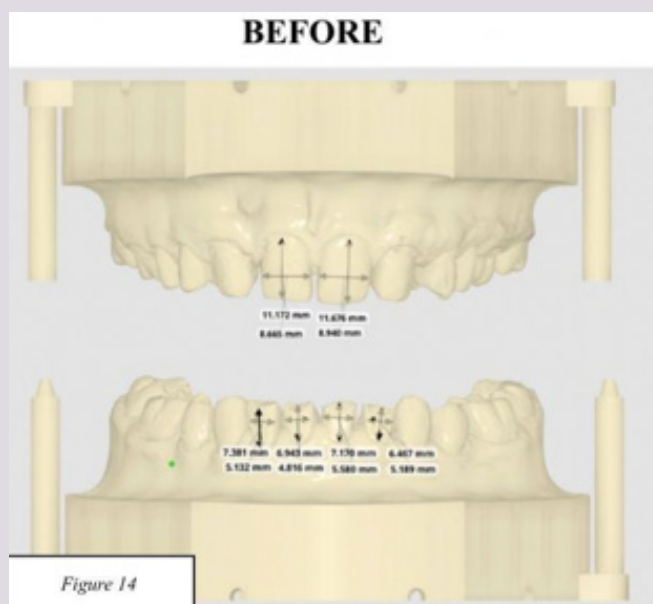
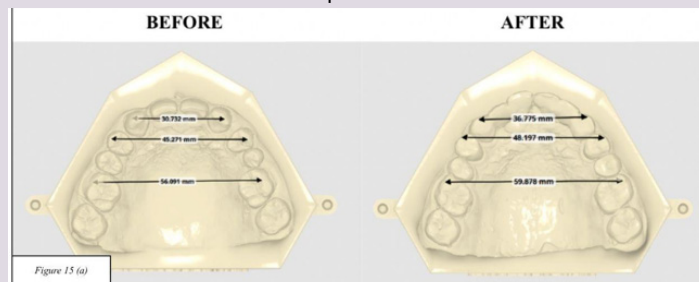


Figure 15

Traverse Measurement

15A. Rotation of teeth #s 16 and #26 created a wider arch on the molar area, improved marginal ridge, and achieved the space needed for the upper lateral incisors. Intercanine width on the previous cast was shorter because the canine was positioned in the lateral incisor area.



15B. The ideal limit of expansion in the lower arch was achieved. Soft tissue limitations in orthodontics: treatment planning guidelines.¹⁸

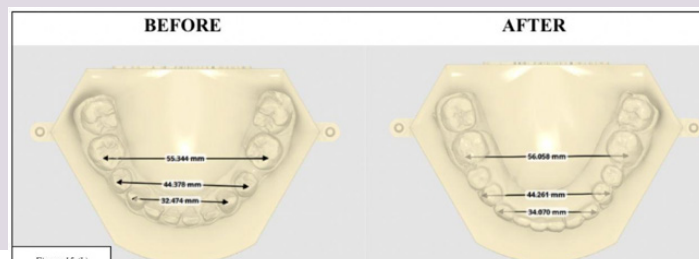


Figure 16

Extra-oral photos of the treatment outcomes

- Facial musculature appears more relaxed, with improved neuromuscular balance
- The patient's facial esthetics significantly improved. The esthetic line (E-line) now falls within normal limits, with a harmonious soft tissue profile. The dental midline is well-centered, complementing facial symmetry and balance.



Figure 17

Panoramic view of the angulation of the roots and crowns and bone health from beginning and middle treatment.

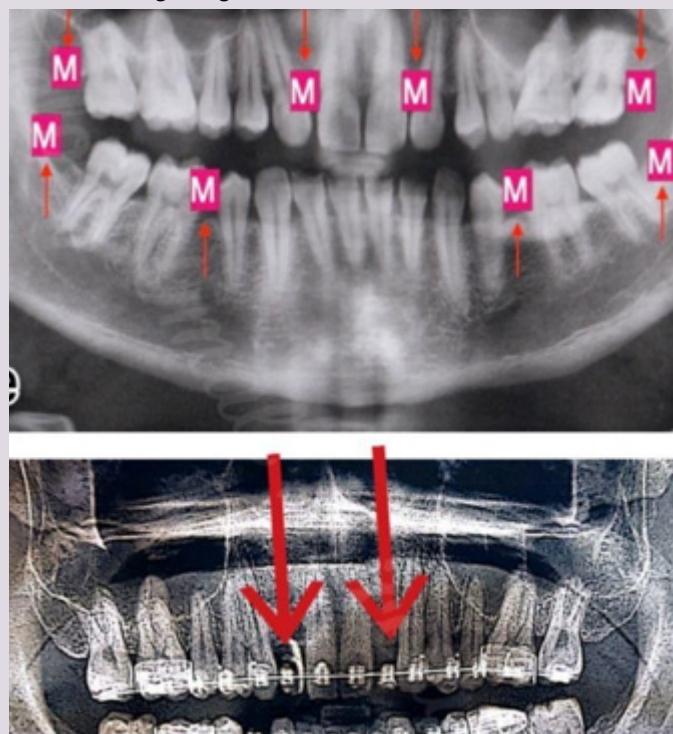


Figure 18

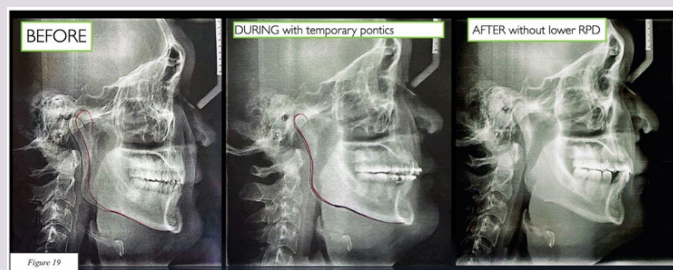
After Treatment

- Residual Spaces: A 0.5 mm space persists between the mandibular first molar and second premolar, accommodating the wire clasp of the removable partial denture.
- Root Parallelism: All roots are generally parallel, with a distal inclination observed on tooth #13.



Figure 19

Improved TMJ function, relaxed musculature, and enhanced airway space - allowing better tongue posture and eliminating previous episodes of bruxism.



CONCLUSION

Hypodontia presents varying degrees of severity, yet across all cases, patients share a common desire: to look and feel better. In today's digital age, where esthetic outcomes are increasingly demanded, every patient deserves a careful, individualized diagnosis and a bespoke treatment plan.

- Esthetics-first approach: Beauty guides the plan.
- Function and structure: Harmony and stability must be ensured.
- Growth and biology: Treatment anchored in developmental and physiological realities.
- A truly successful case is not only beautiful and pain free, but also esthetically pleasing, biologically sound, and functionally stable.

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Figure 20

Fig. 20A: Cephalometric Analysis comparison between pre-treatment and post-treatment outcomes.

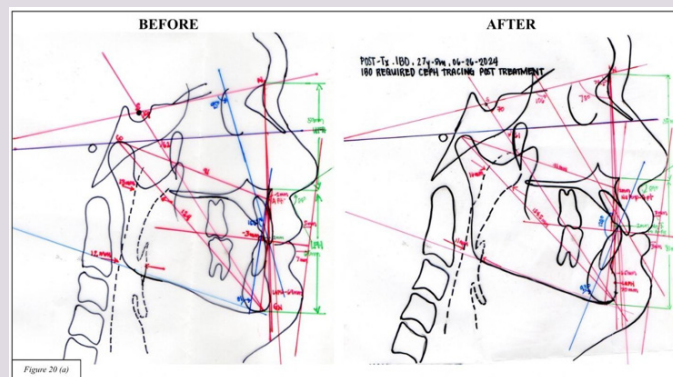


Fig 20B. Cephalometric Analysis Measurement comparison between pre-treatment and post treatment outcomes.

- Maxillary Incisor to SN improved from 95° to 106°, indicating normalized (103°± 2°) axial inclination.
- Mandibular advancement, improving skeletal harmony and anterior tooth inclination.
- Improved Shimbashi measurement from 14.20mm to 19mm (normal range of 17-21mm) supporting vertical dimension and occlusal stability.
- Soft tissue profile refinement, with the patient now achieving an ideal E-line from Upper -5mm to 2mm, from lower of 7mm to 3mm (normal range of -2mm± 2mm)

IBO Cephalometric Data Sheet			
Area	Norm	Pre	Post
1. Analysis of Growth			
a. Stage of Growth	---	Stage V	Stage V
b. Direction of Growth			
Y-Axis to SN	66° +/-2	69	70
Y-Axis to FH	59° +/-2	62	61
2. Analysis of Airways			
a. Upper (nasopharynx)	8-18mm	13mm	16mm
b. Lower (oropharynx)	10-12mm	12mm	11mm
3. Analysis of Skeletal Vertical			
a. FMA	25° +/-5°	21	23
b. LAFH (ANS-Mn)	58-72mm	69mm	70mm
c. UAFH-LAFH/TAHF Ratio	50/50 C		
d. SN-GoMe	45/55 A	46-54	45-55
	32° +/-3°	32	33
4. Analysis of Skeletal Sagittal			
a. Mx Len (Co-A)	---	91mm	91mm
b. Mn Len (Co-Gn)	---	124mm	124mm
c. Mn-Mx Len Difference	(age=mm) 6=17mm 9=20mm	33mm	33mm
d. Wits (Jacobson)	Class I: -2 to 2 Class II: >= 3 Class III: <= -3	-3mm	-2mm
e. SNA	82° +/-3°	80	79.5
f. SNB	80° +/-3°	79	78
g. ANB	2° +/-2°	1	1.5
h. Na Perp - A pt	1mm +/-2mm	-2mm	2mm
5. Analysis of Dento-alveolar Relations			
a. IMPA	95° +/-5	81	93
b. Interincisal Angle	131° +/-4	156	128
c. Mx incisor to SN	103° +/-4	95	106
d. Mn incisor to A-Pg	-1 to 3mm	2mm	2mm
6. Analysis of Soft Tissue			
a. Lower Lip - Esthetic Line	-2mm +/-2	U-(-5mm), L-(-7mm)	
b. Naso-labial Angle	107° +/-11	95	96
c. Lip Seal (present or not)	Yes/No	Yes	Yes

Figure 20 (b)

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Vertical Control of the Maxillary Dentition for Non-Surgical Correction of a Severe Gummy Smile

A Case Report

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ABSTRACT

Correcting the appearance of a gummy smile has long been a challenge, particularly when attempting non-surgical methods. Historically, intruding posterior teeth without skeletal anchorage has been unfeasible, while traditional orthodontic intrusion of anterior teeth often exerts an extrusive force on the posterior teeth. Furthermore, the mechanics involved in space closure can produce undesirable side effects, potentially exacerbating the appearance of the gummy smile. This case report describes the non-surgical correction of a gummy smile through the intrusion of the entire maxillary dentition using skeletal anchorage, along with its long-term retention.

Keywords: gummy smile; intrusion; case report; mini-implants; center of resistance

Conflict of Interest: None

INTRODUCTION

Of all human facial expressions, the smile is the most pleasing and a central feature of facial attractiveness. It is formed by the exposure of teeth and gums during the contraction of muscles in the middle and lower thirds of the face. The smile is shaped by three key components: teeth, gums, and lips. An attractive smile relies on the proper proportion and display of these elements. Ideally, the maxillary lip should symmetrically reveal the maxillary incisors, along with up to 2–3 mm of gum tissue, with the gum line following the contour of the lip. A gummy smile, defined as excessive gingival exposure exceeding three millimeters, is generally considered unaesthetic.¹ The etiologic factors associated with a gummy smile can be grouped into three broad categories:² (1) osseous factors, such as increased vertical height of the maxilla; (2) dental factors, including short maxillary central incisors or altered passive eruption of teeth; and (3) soft-tissue factors, such as a relatively short upper lip, hypermobility of the upper lip muscles, or an

increased width of attached gingiva.

Depending on the etiology of a gummy smile, various non-orthodontic treatment options may be available for correction. Surgical maxillary impaction,^{3,4} clinical crown lengthening,⁵ surgical lip repositioning,^{6,7} and botulinum toxin muscle injections^{8,9} are among the procedures recommended to reduce the appearance of a gummy smile. Orthodontic intrusion of anterior teeth is often proposed to correct a deep overbite.¹⁰ However, achieving true orthodontic correction of a gummy smile may require intrusion of the entire maxillary dentition. Intruding posterior teeth has historically been challenging without the use of skeletal anchorage. Intrusion of anterior teeth typically employs either a one-couple or a two-couple system.¹¹ Regardless of whether a one- or two-couple system is used, a reciprocal extrusive force affects the posterior dentition, making it nearly impossible to intrude the posterior teeth with these methods alone. This case report outlines a technique for intruding the entire maxillary dentition as a non-surgical approach to correcting the appearance of a gummy smile.

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DIAGNOSIS AND ETIOLOGY

A 12-year-old female presented with a chief complaint of excessive overbite and spacing between her upper teeth. Clinical examination revealed a mesoprosopic facial type with a convex soft tissue profile, an acute nasolabial angle, and a severe gummy smile with 100 percent incisal display, along with 6-7 mm of gingival display during a smile. Intraoral examination showed a Class II subdivision malocclusion on the right side, scissor bite on the right first and second premolars as well as the left first premolars, normally inclined upper and lower incisors, 10 mm of space in the upper arch and 5 mm in the lower arch, an 8 mm overjet, a 100 percent deep overbite, and a 4 mm curve of Spee. The upper midline coincided with the facial midline, and no interlabial gap at rest was noted (Figs 1 and 2). The lateral cephalogram revealed a Class II skeletal base (ANB, 70) (Table 1) with a forwardly positioned maxilla, a normally positioned mandible, an average growth pattern, reduced lower facial height, and normal upper facial height.

Figure 1.

Pre-treatment extraoral and intraoral photographs.



Figure 2.

Pre-treatment radiographs



Table I. Cephalometric analysis

	Pre Treatment	Post Treatment
Skeletal		
SNA (°)	86	85
SNB (°)	79	80
ANB (°)	7	6
SN-GoGn (°)	38	36
FMA	28	26
U1-SN (°)	115	110
U1-NA (°)	25	22
U1-NA (mm)	5	2
IMPA (°)	93	100
L1-NB (°)	36	32
U1-NB (mm)	6	3
E line-Upper lip (mm)	2	1
E line-Lower lip (mm)	5	2
UFH (N-ANS) MM	48	47

Treatment Objectives

The treatment objective was to intrude the entire maxillary dentition so that the patient's soft tissue profile on smiling could be improved. Our goal was to close spaces by retraction of maxillary anterior teeth and create a bilateral Class I molar and canine relation.

Treatment Alternatives

Two alternative treatment plans were considered. One plan involved surgical impaction of the maxilla. However, the patient did not exhibit increased upper facial height. Additionally, this procedure could only be performed after the patient had completed growth and would be costly. The patient's parents did not agree to this course of treatment. The extraction of premolars to correct the Class II relationship was also considered. However, this approach would not address the excessive gingival display when smiling. On the contrary, there was a risk of worsening the gummy smile with the extraction plan. Therefore, a non-extraction treatment plan was adopted, which involved intruding the maxillary dentition to correct the severe gummy smile, retracting the anterior teeth, and addressing the Class II relationship.

Treatment Progress

Treatment was initiated by bonding all teeth using a 0.022-inch MBT prescription pre-adjusted edgewise appliance. In the maxillary arch, initial leveling and alignment were performed in segments, with the canines and incisors forming the anterior segment and the premolars and molars forming the posterior segment. The archwire segments were gradually increased to 0.021 x 0.025-inch stainless steel (SS) wires, with crimpable hooks attached mesial to the canines. Two mini-implants (M-Tech, 8 mm length, 1.8 mm diameter) were placed in the anterior region mesial to the canines. Elastomeric chains were applied from the implants to the crimpable hooks to intrude the maxillary anterior teeth. A light elastomeric chain, providing a retractive force, was added from the

Figure 3.

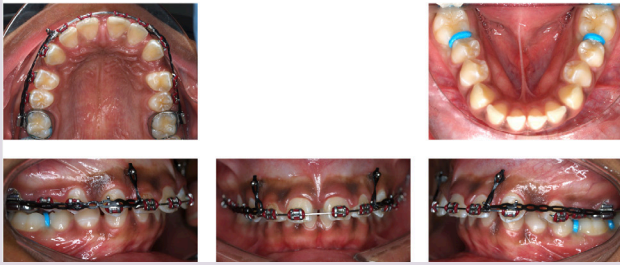


Figure 4.

Intrusion of posterior segment of teeth using mini-implants

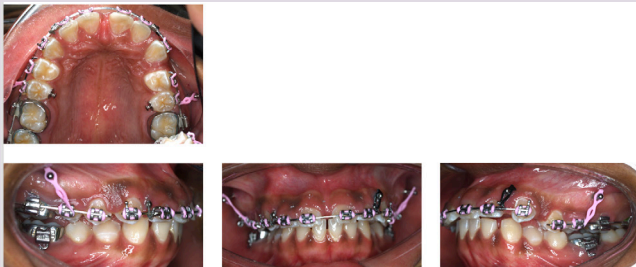


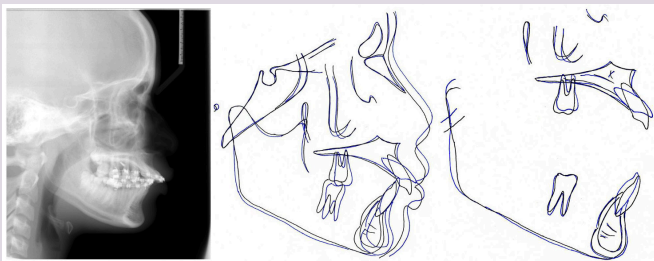
Figure 5.

Placement of continuous archwire after segment intrusion of the anterior and posterior teeth



Figure 6.

Progress lateral cephalogram and superimposition. Black – pretreatment and blue – after anterior and posterior teeth intrusion



crimpable hook to the maxillary molar to redirect the intrusive force along the long axis of the anterior teeth (Fig 3). After three months, the implant on the right side failed, and another implant was placed to continue the intrusion of the anterior teeth. Intrusion of the anterior teeth was performed for five months. Following the intrusion of the maxillary anterior segment, two additional mini-implants (M-Tech, 8 mm length, 1.8 mm diameter) were placed in the interradicular space between the second premolar and the first molar on the buccal side. An intrusive force of approximately 150 cN (centi-Newton) was applied directly from the second premolar bracket to the mini-implants for posterior segment intrusion (Fig 4). To prevent buccal flaring of the posterior teeth during intrusion, the patient was advised to wear a cross-palatal elastic to counteract the moment of force (MF) from the intrusive force. After six months of posterior intrusion, a continuous archwire was placed in the maxillary arch (Fig 5). A progress lateral cephalogram was taken to assess the amount of maxillary intrusion (Fig 6). The maxillary archwire was then upgraded to a stiff 0.019 x 0.025-inch stainless steel wire. En masse retraction of the anterior segment was performed using elastomeric chains from the

Figure 7.

Retraction of the Upper anterior teeth with elastomeric chains from the posterior implants

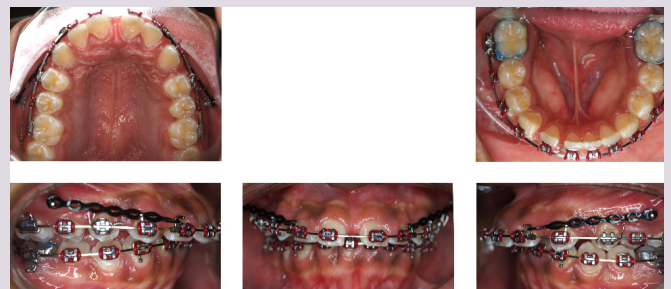


Figure 8.

Post-treatment extraoral and Intraoral pictures intrusion



mini-implants to power arms distal to the lateral incisors (Fig 7).

In the mandibular arch, initial leveling and alignment were accomplished with 0.016-inch NiTi archwires. The archwire was gradually increased to a 0.019 x 0.025-inch SS wire. Reverse-curve archwires were used to level the steep curve of Spee in the lower arch. Class II and settling elastics were applied as needed to settle the occlusion. Finishing and detailing of the occlusion were performed, and the patient was debonded after 26 months of active treatment (Figs 8 and 9). A Hawley removable retainer was provided for the maxillary teeth, and a fixed lingual retainer was placed on the mandibular teeth. The patient was evaluated two years after the completion of treatment, and stable results were observed (Fig 10).

Treatment results

All treatment objectives were achieved. Lateral cephalograms were taken before treatment, after the intrusion of the maxillary dentition, and after treatment. Overall superimpositions were done on the cranial base using the best-fit method. For regional superimposition, Björk and Skieller's¹² structural method was used. Superimpositions after the intrusion phase showed that there was significant intrusion and flaring of the maxillary anterior teeth along with intrusion of the posterior teeth (Fig 6). Overall superimpositions showed intrusion of the maxillary anterior teeth along with maintenance of the vertical position of the maxillary posterior teeth (Fig 11). The mandibular posterior segment underwent mesial movement and extrusion with no distal movement of the lower anterior segment.

DISCUSSION

An attractive smile has been reported to affect the quality of life of an individual by increasing confidence, developing better social skills, increasing job prospects, and other aspects of life.¹³ Treatment for improving the smile of a patient is highly recommended. Correction of a gummy smile involves varied approaches, based on the etiology. Surgical options, while correcting the underlying skeletal discrepancy in patients where a gummy smile is associated with vertical maxillary excess, tend to increase the overall financial burden along with an increased risk of surgical complications as opposed to non-surgical methods. Moreover, surgical correction can only be performed when patients have completed growth, prolonging the wait for esthetic correction. The behavior of perioral muscles also has a significant impact on the smile. This has led to an increase in Botulinum toxin therapy to correct a gummy smile appearance. When injected intramuscularly at therapeutic doses, BTX-A produces partial chemical denervation of the muscles, resulting in localized reduction in muscle activity.¹⁴ The effects of BT therapy are transient requiring frequent drug delivery.¹⁵ Orthodontic mechanotherapy offers a more reliable

Figure 9.

Post-treatment radiographs



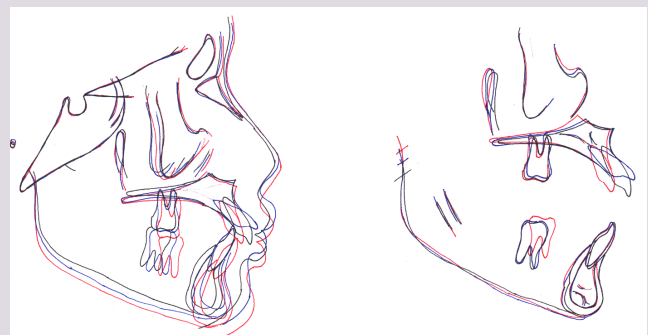
Figure 10.

Two years into the retention with stable results



Figure 11.

Overall and regional superimpositions: pretreatment (black), after intrusion of anterior and posterior teeth (blue), and post treatment (red)



solution at correction of a severe gummy smile and should be advocated when feasible in growing patients. Comparing outcomes between implant and conventional approaches for incisor intrusion,^{16,17} shows that the latter leads to greater extrusion of posterior teeth during incisor intrusion. This can lead to compromised outcomes in patients where intrusion of both the anterior and posterior teeth is desired for correction of a vertically maxillary excess.

Therefore, in this case we attempted intrusion of the entire maxillary dentition using anchorage from mini-implants. We split the intrusion into anterior and posterior segments applying separate mini-implants for each segment. There is not enough literature regarding the intrusion of the entire maxillary arch. However, there are few published case reports¹⁸⁻²⁰ and a case review.²¹ The intrusion of the posterior segments was performed with the help of inter-radicular mini-implants placed buccally between the first and second premolars. While the entire palate is suitable for mini-implant placement, the recommended site is usually around the first premolar region.²² Intrusion of the posterior segment utilizing palatal TADs can also be used for simultaneous intrusion and bite correction. However, inter-radicular regions are generally preferred for palatal TADs based on pain management, patient comfort,²³ and the operator's convenience for implant placement.²⁴ The application of intrusive force was approximately buccal to the CRES (center of resistance) of the posterior teeth. This created a moment of force (MF) tipping the teeth buccal during intrusion. To counteract this moment, the patient was asked to wear a cross-palatal elastic to prevent buccal tipping by generating a counteracting MF.

Structural superimpositions show that while we were able to achieve approximately 3-4 mm of true intrusion during the active intrusion phase (Fig 6), one of the side effects was a significant amount of incisor proclination. This was most likely a by-product of the line of intrusive force not coinciding with the estimated CRES of the maxillary anterior teeth (canine to canine). The CRES of the maxillary anterior segment is generally estimated to be distal to the canine.²⁵⁻²⁷ The intrusive force being applied mesial to this location created a moment of force (MF), causing proclined incisors. A light retraction force was applied from the molar to the canine to counteract the MF (Fig 3). Despite this arrangement, incisors proclined most likely because the intrusion force was greater than the retraction force. Moving forward, clinicians should carefully consider the line of force application in relation to the estimated center of resistance to minimize unwanted tooth movements during anterior intrusion.

During space closure and finishing, there was some relapse of the incisor intrusion, which may be attributed to the inter-arch elastics that were used to settle the occlusion. The smile improvement observed here was a consequence of maxillary incisor retraction and its vertical control during space closure. Retraction of anterior teeth

generally tends to deepen the bite due to the moment of force (MF). This occurs because the point of force application is at the bracket level, which falls below the CRES of the anterior teeth. To minimize moment of force (MF), use of power arms is advocated, so that the point of force application gets closer to the CRES. However, it has been reported that the wire bracket interplay also plays a significant role in the quality of tooth movement. Tominaga et al²⁸ reported that under the influence of play between the wire and bracket, despite placing a power arm passing through CRES, translation of teeth did not occur. The use of a stiff 19x25 steel wire along with a crimpable power hook is reported to provide controlled tipping to translation of teeth during retraction, thus providing significant vertical control in this case.

Age-related changes to the lips might have also contributed to the dramatic change in the smile appearance. It is reported that vertical length of the maxillary lip increases with age.^{29,30} In addition, retraction of the maxillary anterior teeth may have also contributed to the increase in lip length,³¹ thereby assisting in the correction of the patient's gummy smile.

CONCLUSION

This case report demonstrates a non-surgical method of correcting anterior deep overbite and excessive gingival display using mini-implants. In addition to the intrusion of both upper anterior and posterior teeth, we also demonstrated the ways to counteract the undesired forces created by moment of force (MF). Other cost-effective, non-surgical alternatives, which offer greater patient benefits compared to invasive surgical options, need to be further explored.

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External Root Resorption Associated with Displaced Permanent Maxillary Canines: A Cone-Beam Computed Tomographic Analysis

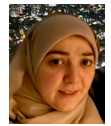
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INTRODUCTION

The maxillary permanent canine tooth is often displaced during eruption and consequently, it is the second-most frequently impacted tooth after the mandibular third molar with a reported incidence of 1.5-3.0%, depending upon population.¹⁻³ The maxillary canine has a long eruption pathway, developing high in the maxilla and moving downward towards the dental arch over a long period of time.⁴ In the maxillary arch, the upper first premolars often erupt before the canine, which means space for this tooth can be at a premium and combined with the long eruption path, displacement can often occur. During normal development, the maxillary canines should be palpable in the buccal sulcus around the age of 10-11 years and erupt around the age of 12 years.⁵ Palatal displacement of the maxillary canine (PDC) is generally more common (80-90%) than buccal displacement (BDC) (10-20%)^{3,6} whilst occasionally, the canine

ABSTRACT

Background: The displaced maxillary permanent canine is a common clinical problem that can be associated with multiple complications including external root resorption (ERR) of adjacent teeth. Objectives: This retrospective cross-sectional observational study investigated ERR associated with teeth adjacent to displaced permanent maxillary canines using cone-beam computed tomographic (CBCT) imaging.

Materials and Methods: The study sample comprised all patients diagnosed with displaced maxillary canine teeth with CBCT imaging available of the anterior maxilla, who attended a tertiary orthodontic-oral surgery treatment planning clinic within a 24-month period between 2018-2020 at Guy's and St Thomas' NHS Foundation Trust, UK. CBCT imaging was analysed to localise the buccal-palatal, vertical and mesio-distal position of the displaced maxillary canines and quantify ERR associated with adjacent teeth. Severity of ERR was assessed based on proximity to the pulp and graded as slight, moderate or severe. Descriptive statistics and logistic regression were used to examine the relationship between canine location and ERR associated with adjacent teeth.

Results: One hundred and nineteen displaced canines were analysed from 92 CBCT scans (41 buccal displaced canines (BDC), 16 in the line of the arch (LOA) and 62 palatal displaced canines (PDC)). ERR was associated with n=44 (37%) displaced canines, with 18.2% of these involving resorption of two adjacent teeth. The teeth most frequently affected by ERR were lateral incisors (73.1%), followed by central incisors (23.1%), and first premolars (3.9%). Interestingly, amongst maxillary central incisor teeth affected by ERR, 58% were classified as severe. BDC were significantly associated with ERR ($P=0.011$), whilst other factors significantly associated with ERR of neighbouring teeth included patient age ≤ 18 years ($P=0.005$) and apical position of the canine crown tip ($P=0.03$). Conclusions: BDC were associated with an increased incidence and severity of root resorption associated with adjacent teeth in the maxilla compared to LOA and PDC.

Keywords: Impacted maxillary permanent canines; Buccal canines; Palatal canines; Displaced canines; Root resorption; CBCT imaging

Conflict of Interest: None

can also become displaced in the line of the arch (LOA). However, the exact proportions vary between different populations.⁷⁻⁹

Displacement of the maxillary canine can be associated with a variety of potential complications, including shortening of the dental arch, tipping of adjacent teeth, ankylosis or follicular cyst formation associated with the canine, and external root resorption (ERR) of adjacent teeth.^{10,11} These can all lengthen and complicate orthodontic treatment for the affected patient and amongst them, local ERR is the most common pathology.^{12,13} Indeed, ERR can occur as early as 9 years of age and reaches the highest frequency at 11-12 years, the normal age of maxillary canine eruption.¹⁴ The risk of ERR is highest for female patients and patients over the age of 14 years,^{5,15} whilst a lack of space for canine eruption in the maxillary arch, canine cusp tip mesial to the midline of the lateral incisor tooth, canine angulation of >25° to the midline and an enlarged follicle around the canine are all associated with increased ERR risk.¹⁵⁻¹⁷ The reported incidence of maxillary canine-induced ERR in the anterior maxilla varies according to the population studied, type of imaging used and the tooth investigated. Certainly, the maxillary lateral incisor would appear to be the most commonly affected tooth, with an overall incidence ranging from 12-38% depending upon whether conventional radiography or cone beam computed tomography (CBCT) imaging is used.^{8,12,18,19} Less commonly, the maxillary central incisor (2-23%) and first premolar (around 4%) can also be affected.^{8,17,20}

The buccal-palatal location of a displaced maxillary canine is also a potential risk factor for ERR although data on PDC are unclear. A number of previous studies have not found an association between ERR and buccal-palatal location,²¹⁻²⁴ although there is some evidence from CBCT imaging for an increased incidence with BDC^{7,17} that has also been confirmed in a subsequent systematic review.²⁵ Given that the lateral incisor root is covered by a larger area of cancellous bone on the palatal aspect compared to the thin buccal cortical bone, this might potentially explain the increased susceptibility of the lateral incisor to ERR in the presence of a BDC compared to PDC.

This retrospective observational study utilised CBCT imaging to investigate the relationship between maxillary canine displacement and ERR of adjacent teeth. The null hypothesis was that no significant differences exist in ERR associated with teeth adjacent to displaced maxillary canine teeth according to position of the canine.

MATERIALS AND METHODS

Approval for this retrospective cross-sectional, observational study was granted by Guy's and St Thomas' NHS Foundation Trust as a service evaluation (Ref: 11087).

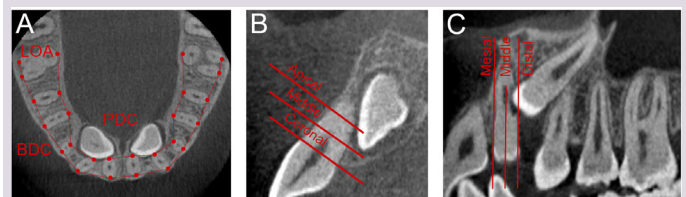
The study sample comprised all patients diagnosed with displaced maxillary canine teeth with CBCT imaging available of the anterior maxilla, who attended a tertiary orthodontic-oral surgery treatment planning clinic over a 24-month period between January 2018 and January

2020 at Guy's and St Thomas' NHS Foundation Trust. The following exclusion criteria were applied: any patients diagnosed with cleft lip/palate or craniofacial syndrome, any history of orthodontic treatment prior to or at the time of CBCT imaging, any history of dental trauma or maxillary surgery, or any CBCT imaging with an incomplete view of the anterior maxilla/maxillary teeth.

All CBCT imaging was obtained using a 3DX Accuitomo 170 (J Morita, Kyoto, Japan) at 2-6 mA and 90 kV with a voxel size range 0.08-0.16 mm³, and performed according to manufacturer recommendations. CBCT records were randomly coded and analysed blind using Sectra PACS IDS7 (Sectra AB, Sweden) and i-Dixel (J. Morita MFG Corp, Kyoto, Japan) software on a 54 cm colour display flat-screen monitor (2-megapixels resolution) (EIZO RadioForce, Japan) by a single evaluator (ZAA) who completed United Kingdom CBCT Level 1 (Core Theory Training) and Level 2 (Hands-On Justification and Interpretation) in November 2020. The following parameters were recorded for each patient: (1) age and gender at the time of imaging; (2) unilateral (right or left) or bilateral canine displacement; (3) buccal-palatal position of the canine crown (using the CBCT axial view) and defined as BDC, LOA or PDC (Fig. 1A): if >half of the canine crown was located outside a line constructed to define the buccal or palatal surfaces of neighbouring teeth, the canine was deemed to be BDC or PDC, respectively;²¹ (4) vertical position of the canine crown tip relative to the adjacent incisor root (using the CBCT sagittal view) and defined as apical, middle or coronal (Fig. 1B): apical=apical to or within the apical

Figure 1.

Canine 3D localisation using CBCT imaging. (A) Buccal-palatal position of the canine crown (using the CBCT axial view) was located using lines constructed to define the buccal and palatal surfaces of neighbouring teeth (red lines). The canine was deemed to be BDC, PDC or LOA, respectively in relation to these lines (21); (B) Vertical position of the canine crown tip relative to the adjacent incisor root (using the CBCT sagittal view) and defined as apical, middle or coronal based upon lines constructed at the cervical margin of the crown (coronal), root apex (apical) and a line equidistant between these two (apical=apical to or within the apical third, middle=within the middle third or coronal=within the coronal third of the incisor root tip, respectively); (C) Mesio-distal position of the canine crown tip relative to the most mesial contour of the adjacent incisor root and the axis of the lateral incisor (using the CBCT coronal view) and defined as mesial, middle or distal based upon lines constructed at the mesial, middle and distal edges of the lateral incisor (mesial= mesial to the incisor root, middle=between the axis of the lateral incisor and the mesial contour or distal=distal to the axis of the lateral incisor's root, respectively).



third, middle=within the middle third or coronal=within the coronal third of the incisor root tip, respectively;⁵ mesio-distal position of the canine crown tip relative to the most mesial contour of the adjacent incisor root and the axis of the lateral incisor (using the CBCT coronal view) and defined as mesial, middle or distal (Fig. 1C): mesial=mesial to the incisor root, middle=between the axis of the lateral incisor and the mesial contour or distal=distal to the axis of the lateral incisor's root, respectively);⁶ ERR of adjacent teeth was assessed using sagittal, coronal and axial views orientated along the long axis of the root under examination, and defined according to presence or absence; teeth affected; depth (classified according to¹² as slight: extending less than half the dentine thickness towards the pulp; moderate: extending from the midway point of dentine thickness towards the pulp and beyond, but the pulp lining remaining intact; severe: pulp exposed by the resorption); and location (in relation to the long axis of the resorbed tooth: apical, middle or cervical third of the root, or a combination of regions – apical and middle or apical, middle and cervical).

Data were analysed using Stata version 16 (StataCorp LP, College Station, TX). Descriptive statistics at the level of the patient and at the level of the displaced canine were used to report the data including absolute/relative frequencies for categorical variables and median with interquartile ranges (IQR) for continuous variables (after appropriate testing with the Shapiro-Wilk test). Differences in ERR according to canine localization were tested overall or separately for BDC/PDC with logistic regression (accounting for within-patient clustering with robust standard errors) and expressed as odds ratio (OR) with their 95% confidence intervals (CI). Statistical significance was assumed at a two-sided $p=0.05$ and the dataset was openly provided (DOI 10.5281/zenodo.12626770).

Ten CBCT images were randomly selected after 1 month for repeat examination (ZAA) or analysis by a second observer (GK) for ERR (slight, moderate or severe) to test for intra-rater and inter-rater reliability, respectively using Cohen's kappa statistic. Intra-rater and inter-rater agreement scores were both 1.00 ($p<0.0001$), which demonstrated perfect agreement for determining the severity of ERR.

Table 1

Descriptives at the level of displaced canine position

Variable	Category	N ^a	Descriptive
Buccal-palatal position	BDC – n (%)	119	41 (34.5%)
	PDC – n (%)	119	62 (52.1%)
	LOA – n (%)	119	16 (13.5%)
Vertical position	Apical – n (%)	119	43 (36.1%)
	Middle – n (%)	119	61 (51.3%)
	Coronal – n (%)	119	15 (12.6%)
Mesio-distal position	Mesial – n (%)	119	84 (70.6%)
	Middle – n (%)	119	11 (9.2%)
	Distal – n (%)	119	24 (20.2%)

N^a, available observations

Table 2

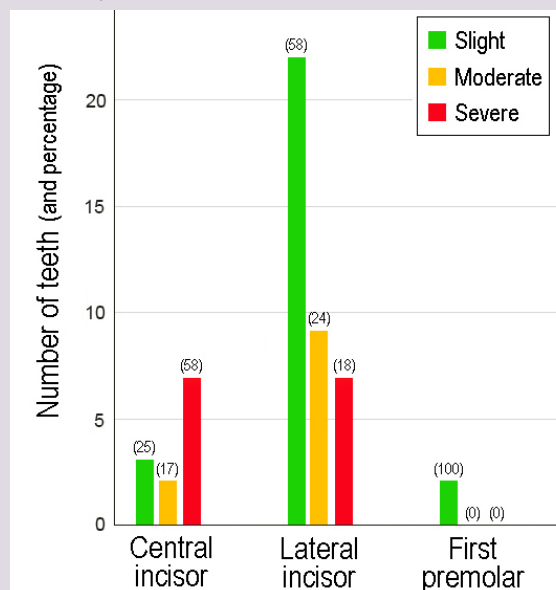
Descriptives at the level of neighboring teeth affected by ERR

Variable	Category	N	Descriptive
Tooth type affected by ERR	Central incisor – n (%)	52	12 (23.1%)
	Lateral incisor – n (%)	52	38 (73.0%)
	First premolar – n (%)	52	2 (3.9%)
Depth of ERR	Slight– n (%)	52	27 (51.9%)
	Moderate– n (%)	52	11 (21.2%)
	Severe– n (%)	52	14 (26.9%)
Location of ERR	Apical third – n (%)	52	34 (65.4%)
	Middle third – n (%)	52	11 (21.2%)
	Cervical third – n (%)	52	0 (0%)
	Apical and middle third– n (%)	52	3 (5.8%)
	Apical, middle and cervical third– n (%)	52	4 (7.7%)

N^a, available observations.

Figure 2

Histogram representing the number of teeth affected by ERR in the total sample (percentages are also shown in brackets for each ERR category in relation to each adjacent tooth).



RESULTS

Ninety-seven anterior maxillary CBCT scans with displaced maxillary canines were identified with five scans excluded due to quality of the imaging, the canine tooth not being sufficiently visible for analysis, or the patient already undergoing orthodontic treatment prior to the scan. A total of 92 CBCT scans were therefore analysed from 92 individual patients consisting of n=26 (28%) males and n=66 (72%) females. Amongst this group, the overall median age was 14 (IQR 13-16.5) years with n=50 (55%) of the sample <15 years of age, n=24 (26%) 15-18 years of age and n=18 (19%) ≥ 18 years of age.

A total of 119 displaced canines were analysed from the CBCT imaging, with n=65 (71%) unilateral and n=27 (29%) bilateral. Amongst the unilateral displaced canines, n=31 (48%) were situated on the right-side and n=34 (52%) on the left-side of the maxilla. Descriptive statistics at the level of displaced canine position are shown in Table 1. The majority of canines were defined as PDC (52.1%) with the tip of the crown orientated in the middle third vertically (51.3%) and mesial to the adjacent incisor root horizontally (70.6%).

ERR was identified in association with n=44 (37%) of the displaced canines, and amongst these teeth, n=36 (82%) had ERR associated with one neighbouring tooth, whilst n=8 (18%) had ERR associated with two teeth. Table 2 shows descriptive statistics for ERR at the level of neighbouring teeth and Figure 2 demonstrates the distribution of ERR severity for each type of tooth. Overall, lateral incisors were the worst affected by ERR whilst the first premolars were the least commonly affected; however, proportionally, more central incisors were affected by severe ERR.

The effect of displaced canine localisation on ERR is shown in Table 3. ERR was most often seen in association with BDC, followed by PDC and then those in the LOA. In addition, BDC were more likely to cause ERR in two adjacent teeth. Severe ERR was observed in twice as many BDC when compared with PDC. The relationship between buccal-palatal position of the displaced canine crown and ERR was significant. Logistic regression showed a statistically significant difference in ERR in association with a BDC (P=0.011) (Table 4).

Table 5 shows factors associated with ERR of neighbouring teeth from BDC and PDC or

Table 3

Cross-tabulation on the effect of displaced canine localisation on ERR of neighbouring teeth

Variable	Category	LOA	BDC	PDC
ERR	No – % (n)	81.3% (13)	41.5% (17)	72.1% (44)
	Yes – % (n)	18.8% (3)	58.5% (24)	27.9% (17)
Teeth resorbed	None – % (n)	81.3% (13)	41.5% (17)	72.1% (44)
	One tooth – % (n)	18.8% (3)	43.9% (18)	23.4% (15)
	Two teeth – % (n)	0% (0)	14.6% (6)	3.3% (2)
Depth of ERR	Slight – % (n)	33.3% (1)	43.3% (13)	63.2% (12)
	Moderate – % (n)	0% (0)	23.3% (7)	21.1% (4)
	Severe – % (n)	66.7% (2)	33.3% (10)	15.8% (3)

Table 4

Logistic regression on the effect of localisation of the displaced canine on ERR of neighbouring teeth

Variable	Category	OR	95% CI	P
Localisation	LOA	Reference		
	BDC	6.12	1.51, 24.71	0.011
	PDC	1.67	0.41, 6.87	0.47

CI, confidence interval; OR odds ratio.

Table 5

Logistic regression on factors associated with ERR of neighbouring teeth from BDC and PDC

Variable	Category	Buccal / palatal OR (95% CI)	P	Only buccal OR (95% CI)	P	Only palatal OR (95% CI)	P
Patient age	Per year	0.92 (0.84, 1.00)	0.05	0.99 (0.84, 1.16)	0.91	0.92 (0.81, 1.04)	0.19
Age category	<15 years	Reference		Reference		Reference	
	15-18 years	0.47 (0.18, 1.25)	0.13	0.46 (0.11, 1.88)	0.28	0.36 (0.09, 1.45)	0.15
	≥ 18 years	0.15 (0.04, 0.57)	0.005	0.56 (0.03, 10.22)	0.69	0.07 (0.01, 0.61)	0.02
Gender	Male	Reference		Reference		Reference	
	Female	0.88 (0.37, 2.09)	0.78	0.64 (0.18, 2.33)	0.50	0.54 (0.15, 1.87)	0.33
Vertical position of canine crown tip	Coronal	Reference		Reference		Reference	
	Middle	3.50 (0.71, 17.25)	0.12	0.63 (0.17, 2.41)	0.50	0.86 (0.14, 5.11)	0.87
	Apical	6.20 (1.19, 32.34)	0.03	-	-	2.10 (0.32, 13.87)	0.44
Mesio-distal position of canine crown tip	Distal	Reference		Reference		Reference	
	Middle	1.98 (0.67, 5.82)	0.21	3.33 (0.57, 19.42)	0.18	1.08 (0.18, 6.47)	0.93
	Mesial	2.50 (0.56, 11.16)	0.23	1.67 (0.19, 14.75)	0.65	3.00 (0.23, 38.63)	0.40

CI, confidence interval; OR, odds ratio.

BDC and PDC in isolation. For both BDC and PDC, younger patient age (≤ 18 years) and an apical vertical position of the canine crown tip were significantly associated with an increased likelihood of ERR. Conversely, patient age ≥ 18 years was associated with significantly reduced odds of adjacent ERR overall (OR=0.15, 95% CI: 0.04-0.57, $P=0.005$) and in PDC specifically (OR=0.07, 95% CI: 0.01-0.61, $P=0.02$).

DISCUSSION

The aim of this retrospective, cross-sectional observational study was to investigate the relationship between maxillary canine displacement and ERR associated with adjacent teeth using a sample of patients with CBCT imaging data of this region.

The sample was obtained from a cohort of consecutive patients attending a tertiary oral surgery-orthodontic multidisciplinary clinic in a busy university hospital setting over a two-year observation period. The sample demographics reflect the findings of previous studies investigating associations with maxillary canine displacement in a European population; sexual dimorphism (2.5 females affected for every male in the present sample),²⁶ the majority of subjects with unilateral impaction⁶ and a comparable gross distribution of PDC and BDC.^{22,27,28}

We found associations between the position of displaced maxillary canines and ERR affecting adjacent teeth, which is contrary to a number of studies reporting no differences in ERR caused by PDC and BDC.²¹⁻²⁴ In the current sample, BDC not only caused ERR in the greatest number of teeth, but they were also more likely to resorb more than one adjacent tooth and cause more severe ERR, extending to the pulp. In addition, canines located mesial to the lateral incisor midline also resulted in more ERR, which is consistent with other studies that found physical proximity of the canine to the incisor root correlating with ERR.^{3,7,8,23,28} Thus, BDC situated mesial to the lateral incisor midline should be considered high risk for ERR in association with this tooth. Clinicians should be aware of this risk and consideration should be given to early supplementation of the clinical examination with appropriate imaging to avoid a late diagnosis of ERR. These lesions can be rapidly progressive and early diagnosis will influence the management plan for the displaced canine.¹⁰

CBCT has been proven to be an effective method of diagnosing the prevalence and severity of ERR associated with teeth adjacent to displaced maxillary canine teeth. The technique enables detection of ERR with high accuracy compared to plain film radiography.⁶ The relative proportions of patients identified with ERR in the present study were high in comparison to similar studies^{8,17,23,27} although this might be expected given that the patient sample was derived from a tertiary clinic dealing with individuals affected by significant displacement of maxillary canine teeth. Furthermore, our findings demonstrated that patients younger than 18 years had

significantly higher odds of ERR compared to those aged 18 years and older (OR=0.15, $P=0.005$). This observation is biologically consistent with the active eruptive phase of the maxillary canine. Canine-induced root resorption is largely driven by active eruption pressure and physical proximity during dental development, which reaches peak activity between 11 and 15 years of age.

The maxillary lateral incisor root is often the area most affected by ERR, followed by the maxillary central incisor and the least affected tooth being the first premolar.^{3,17,21,22} The high relative risk of ERR in association with the maxillary lateral incisors has been attributed to three main factors: (1) inclination of the displaced canine, especially if it overlaps more than 50% of the lateral incisor crown and has a well-developed root;^{6,12} (2) the maxillary lateral incisor often has a conical root and demonstrates an increased incidence of abnormal root morphology, and (3) the root of this tooth is often positioned deep in the palate where the maxillary canine frequently develops, making it prone to direct contact and resorption of the incisor (4).

LIMITATIONS OF THE STUDY

This investigation was a retrospective observational study of orthodontic patients with displaced maxillary canine teeth referred for CBCT imaging. Although a common methodology for these types of investigation, there is a risk of selection bias. Justification for the use of CBCT in these cases is primarily through a need for definitive three-dimensional localisation of maxillary canine position and the relationship of this tooth to neighbouring structures, and to provide diagnostic information relating to possible ERR associated with adjacent teeth. Therefore, by default the sample is likely to comprise of more severe cases of canine displacement and potential ERR. The association between buccal-palatal position of the maxillary canine and ERR does not mean we can assume a causal relationship with our study design and we were unable to perform a meaningful logistic regression model of factors associated with ERR in adjacent teeth because of the limited sample size and number of events in each category. A larger sample size would be necessary to carry out more complicated analyses and identify significant factors related to canine position and ERR.

CONCLUSIONS

This retrospective observational study has investigated 92 subjects with 119 displaced maxillary canine teeth and found ERR in adjacent permanent teeth associated with 37% of displaced canines, with 18.2% of these canines resorbing two adjacent teeth. ERR affected 73.1% of lateral incisors, 23.1% of central incisors and 3.9% of first premolars. Most ERR affecting the central incisors was severe, extending to the pulp. Most ERR occurred at the apical third of adjacent teeth and a significant relationship existed between the buccal-palatal position of the

displaced canine and ERR. BDC caused more severe ERR and at a higher frequency compared to PDC and those in the LOA.

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Bonding Orthodontic Metal Brackets to Composite Restorations: An Evaluation of the Bonding Effectiveness of Two Adhesive Systems

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ABSTRACT

Objectives: Bracket bond failure is a common issue in orthodontics, especially with composite restorations. The shear bond strength of metal brackets that are bonded to composite surfaces using Single Bond 2 and Single Bond Universal Adhesive is compared in this study. Also, it evaluates the effects of surface preparation with diamond burs.

Methods: In this experimental study, 48 composite specimens were prepared and randomly assigned into four groups ($n = 12$) based on adhesive type and whether surface preparation with a diamond bur was performed. MBT metal brackets were bonded to composite surfaces. Shear bond strength and failure patterns were evaluated after 50,000 thermocycling cycles. A stereomicroscope was used to determine the mode of failure and adhesive remnant index (ARI) score. Data were analyzed using SPSS version 23, two-way ANOVA, and the Kruskal-Wallis test.

Results: The strength of the shear bond was significantly greater in Single Bond Universal Adhesive groups than in those treated with Single Bond 2 ($P = 0.001$). Bond strength did not significantly change after preparing the surface with a diamond bur ($P = 0.913$). The single bond universal groups had the most frequently observed Adhesive Remnant Index (ARI) score (score 4).

Conclusions: Bonding orthodontic brackets to composite restorations is more effective with universal adhesives, which improve bond strength, reduce clinical chair time, and guarantee reliable bracket retention throughout treatment.

Keywords: Bracket bond failure, Composite restoration, Orthodontic bracket, Shear bond strength, Universal adhesive.

Conflict of Interest: None

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INTRODUCTION

The clinical success of fixed orthodontic treatment depends to a large extent on the stable adhesion of orthodontic metal brackets (OMB) to the enamel surface. Problems that may arise during the treatment process, such as increased chairside time, prolonged treatment duration, and enamel damage, such as demineralization, are potential consequences of bracket bond failure (BBF). The performance of the adhesive system at the bracket-enamel interface is a major factor in these problems, and a reliable index such as bond integrity is needed to properly measure the shear bond strength (SBS).¹⁻³ Orthodontic brackets are widely believed to require a minimum SBS of between 5.9 and 7.8 MPa, which is sufficient to withstand functional forces during treatment. Clinical success cannot be achieved without a durable bond, and it is dependent on factors like adhesive selection, bracket base design, and operator technique.^{4,5}

The incidence of BBF during treatment is reported to be 4.4%,

making it a common phenomenon.⁶ BBFs are observed more frequently in younger patients, males, patients with inadequate oral hygiene, and those presenting with Class II malocclusion, deep overbite, or pronounced overjet. This problem is most prevalent in the posterior teeth, specifically the mandibular premolars and molars, but it can also happen in the anterior teeth if there is increased overjet and overbite.^{6,7} BBF could be caused by occlusal forces, bonding errors, or an inadequate enamel response to etching.^{8,9}

Adhesive dentistry has recently introduced new monomers and silanes to improve chemical adhesion to tooth structures, porcelain, and composite restorations. The advancements have made application processes easier and improved bond persistence. Furthermore, the use of bioactive molecules and monomers that can withstand degradation has increased in mechanical strength.¹⁰ Attaching orthodontic brackets to surfaces other than healthy enamel, such as existing dental restorations or enamel compromised by conditions like amelogenesis imperfecta, can be challenging, often leading to weaker bond strength and an increased chance of bracket failure.^{11,12} Improved bracket bond strength can be achieved by focusing on bracket design, adhesive selection, and surface treatment. Recent innovations, such as advanced adhesives and primers, have improved bonding outcomes.^{13,14} While etch-and-rinse systems may offer higher SBS, they may also cause more enamel damage. By removing the etching step, universal adhesives (UAs) can give comparable SBS with less enamel damage.¹⁵⁻¹⁷ Nevertheless, more research is needed to confirm their long-term effectiveness as a bonding agent for orthodontic bracket bonding to composite restoration.

This study aimed to assess the SBS of orthodontic metal brackets to composite restorations using two distinct bonding systems: Single Bond 2 (SB2: 3M™, ESPE-USA) and Single Bond Universal Adhesive (SB-UA: 3MTM, ESPE-Germany). Additionally, the impact of preparing the composite surface with diamond burs on bond strength was examined.

METHOD AND MATERIALS

This experimental in vitro study involved 48 central Incisor tooth composite specimens made from a nano-hybrid composite (Filtek Ultimate, 3M), each measuring 2×8 mm, using central tooth templates. The specimens were subdivided into four groups that each contained 12 specimens (Figure 1). Plastic molds were filled with composite material in increments of 2 mm, with each layer being polymerized for 20 seconds with a light-curing unit. The specimens were embedded in cold-cured acrylic blocks of various colors after fabrication. To simulate clinical bonding conditions for OMBs, all specimens were incubated at 37°C for 24 hours.

The specimens were allocated into four groups based on bonding agent and surface preparation as follows:

- **G1 (clear):** Single Bond Universal adhesive (SB-UA) without surface preparation.
- **G2 (blue):** Single Bond Universal adhesive (SB-UA) with diamond bur roughening.
- **G3 (yellow):** Single Bond 2 adhesive (SB2-A) without surface preparation.
- **G4 (red):** Single Bond 2 adhesive (SB2-A) with diamond bur roughening.

Figure 1.

Prepared central tooth specimens mounted in acrylic blocks; specimens in the red and blue groups received diamond bur surface



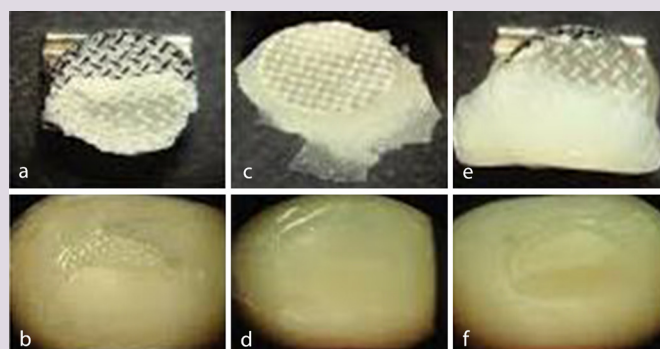
This four-group design allowed for separate and combined assessment of adhesive type and surface treatment on bracket SBS.

A medium-grit diamond fissure bur was used to roughen the composite surfaces in groups 2 and 4 (blue and red). Continuous water irrigation was used to pass the bur over each sample's surface three times clockwise at high speed. All specimens were then etched with 37% phosphoric acid for 15 seconds, rinsed with water for 30 seconds, and dried with air for 30 seconds. For 20 seconds, Universal Adhesive was applied to groups 1 and 2, and Single Bond 2 was applied to groups 3 and 4, as part of the bonding process. After 5 seconds of gentle air drying, the adhesives were light-cured at 650 mW/cm² for 20 seconds.

Twenty-four hours later, MBT System .022 Maxillary Central brackets (3M) were bonded to the specimen surfaces by an experienced operator using composite adhesive (Ormco Grengloo Adhesive, Italy). To standardize bonding pressure, a tension-compression gauge applying 100 grams of force was used. The bonded brackets were light-cured at 650 mW/cm² for 40 seconds. Specimens were then mounted in acrylic blocks (Parsdental, Tehran, Iran), ensuring the slots were horizontally aligned (Figure 2).

Figure 2.

Representative images of ARI scores: (a, b) S2; (c, d) S3; (e, f) S4.



After incubation at 37°C for 24 hours, the specimens underwent 50,000 thermocycling cycles between 5°C and 55°C over six days to simulate oral temperature fluctuations before testing SBS. The shear force needed to debond the brackets was measured using an Instron testing machine (Zwick/Roell Z2020, Germany) at a speed of 0.5 mm/min. The thermocycling and shear bond testing were performed consecutively, followed by the calculation of SBS. Fracture patterns were evaluated under a stereomicroscope.

The amount of adhesive remaining on the specimen surfaces after bracket removal was assessed using the ARI, following the method described by Artun and Bergland.¹⁸ Finally, bond strength data for all groups were analyzed with two-way ANOVA and Tukey HSD post hoc tests. The Kruskal-Wallis test was applied to evaluate differences in ARI scores between groups.

Data were analyzed using SPSS version 23 with a significance level set at 0.05. Differences in SBS among groups were evaluated using two-way ANOVA, and failure pattern distributions were analyzed with the Kruskal-Wallis test.

RESULTS

This study aimed to evaluate the SBS of orthodontic metal brackets bonded to composite restorations using two different adhesive systems. It also examined the effect of surface roughening with diamond burs on SBS. The SBS outcomes for the experimental groups are presented in Table 1.

The distribution of SBS data in all groups was confirmed to be normal. The homogeneity of variances assumption required for ANOVA was also satisfied ($P = 0.24$). Therefore, a Two-Way ANOVA was conducted to compare the mean SBS among the groups. The analysis revealed a significant difference between the SB-UA and SB2 groups. However, no significant interaction was found between the type of bonding agent and surface roughening ($P = 0.855$). Additionally, the comparison between surface preparation by diamond bur roughening and no surface preparation showed no significant difference ($P = 0.913$); the SB-UA group exhibited higher SBS than the SB2 group, regardless of surface roughening ($P = 0.001$).

Table 2 summarizes the results of the assessment of adhesive remnant on composite surfaces after bracket

Table 1

Mean and Standard Deviation of SBS

Adhesive Type	N	Mean (MPa) $\pm$ SD
SB-UA + No SP	12	37.07 $\pm$ 4.34
SB-UA + SP	12	37.26 $\pm$ 12.10
SB2-A + No SP	12	28.85 $\pm$ 6.15
SB2-A + SP	12	28.12 $\pm$ 9.63
SB-UA: Single Bond Universal Adhesive, SB2-A: Single Bond 2 Adhesive, SP: Surface Preparation with Diamond Bur.		

Table 2

Distribution of Failure Patterns.

			ARI					Total
			S0	S1	S2	S3	S4	
Group	SB-UA + No SP	Count	0	0	0	6	6	12
		%within Group	0%	0%	0%	50%	50%	100%
	SB-UA + SP	Count	0	0	0	3	9	12
		%within Group	0%	0%	0%	25%	75%	100%
	SB2-A + No SP	Count	0	0	0	10	2	12
		%within Group	0%	0%	0%	83.3%	16.7%	100%
	SB2-A + SP	Count	0	0	0	10	2	12
		%within Group	0%	0%	0%	83.3%	16.7%	100%
Total		Count	0	0	0	29	19	48
		%within Group	0%	0%	0%	60.5%	39.5%	100%
SP: Surface Preparation with Diamond Bur.								

debonding using a stereomicroscope. The definition of ARI scores was as follows:

- **Score 0:** No adhesive residue remains on the surface.
- **Score 1:** Adhesive covers less than half of the surface area.
- **Score 2:** Adhesive covers more than half of the surface area.
- **Score 3:** Adhesive covers the entire surface.
- **Score 4:** Fracture of the surface is observed.

In Group 1, 50% of the specimens scored 4. Group 2 showed 75% of specimens at score 4. In Group 3, 16.7% of specimens scored 4, while in Group 4, 83.3% of specimens scored 3.

The Kruskal-Wallis test was used to analyze failure pattern differences between the groups, revealing a significant distinction between the SB-UA and SB2-A groups ($p = 0.008$).

DISCUSSION

Successful bonding in orthodontic treatment depends on three key factors: proper tooth surface preparation, precise bracket base design, and selection of an appropriate bonding agent. To achieve optimal bonding performance on both labial and lingual surfaces, several steps should be followed, including initial cleaning, enamel surface conditioning, sealant application, bonding agent placement, and final light curing.^{19,20} Mechanical surface preparation, such as laser etching, sandblasting, peeling, and grinding, alters the surface topography and increases roughness, thereby enhancing mechanical retention and thermodynamic interactions between the adhesive components. Conversely, chemical methods like plasma treatment improve bond strength by increasing the chemical energy of bonds between the adhesive and the substrate.²¹ Multiple factors influence the bond strength between brackets and tooth enamel, including the type of enamel surface preparation material, the concentration and duration of acid etching, adhesive composition and viscosity, thickness of the bonding layer, bracket base design, bracket material, and surface characteristics of the bonding area.²² Consequently, recent research has focused on improving bond strength to composite surfaces while minimizing surface preparation.

Traditional orthodontic metal bracket bonding involves a three-step process of enamel conditioning, priming, and adhesive application; however, newer two-step systems using self-etching and self-adhesive adhesives have been developed to streamline procedures and reduce errors.²³ This study compared SB-UAs and SB2-As for bonding metal brackets to composite surfaces and found that SB-UAs provided consistently higher SBS, regardless of surface treatment. These findings align with previous studies demonstrating that UAs deliver stronger bonds than conventional multi-step adhesives in both etch-and-rinse and self-etch modes.^{24,25} UAs improve bonding uniformity across various substrates, though bond durability may depend on the substrate's nature.²⁶ Proper application and storage are crucial for optimal performance, with HEMA-free

adhesives containing methacrylamide showing enhanced long-term stability.²⁷

Compared to freshly placed composite resins, aged composite restorations lack a superficial layer rich in unpolymerized methacrylate groups, which impedes direct chemical bonding with orthodontic adhesives. Additionally, prolonged exposure to the oral environment can degrade the polymer matrix of the composite material.^{28,29} However, sufficient SBS can still be achieved through mechanical surface preparation techniques, such as roughening with diamond burs or sandblasting. For example, Fathpour et al. found that air abrasion followed by adhesive application, with or without the use of a primer, was the most effective method for repairing zirconia restorations veneered with resin composites.³⁰ In contrast, another study that investigated acid etching followed by laser treatment concluded that laser surface preparation is not advisable for bonding to aged restorations.³¹

Bonding orthodontic metal brackets to aged composite surfaces remains challenging in restorative and orthodontic dentistry. Various mechanical (e.g., milling, sandblasting) and chemical (e.g., acid etching, silane application) surface treatments have been used, but their effectiveness is inconsistent across studies.³² While adding a silane step before UA may not significantly enhance SBS,³³ silane remains important when bonding directly to the composite, as UA alone may be insufficient.³⁴ Individually, surface roughening, primers, and silane improve SBS, but their combined use does not produce additional benefits.³⁵ Primer use significantly increases bonding strength compared to no primer.³⁶ Additionally, combining oral air abrasion with etching during re-bonding achieves higher SBS than etching alone and can surpass initial bonding strength.³⁷ Overall, the protocol of diamond bur roughening followed by silane and adhesive application (total-etch or self-etch) is still considered the most effective for enhancing micro-tensile and micro-SBS.²⁹

CONCLUSION

This study demonstrated that UAs significantly improve the SBS of orthodontic metal brackets bonded to composite surfaces compared to conventional adhesives, regardless of whether surface roughening with a diamond bur was performed. Surface preparation did not significantly affect bond strength within the UA groups. Furthermore, higher ARI scores in the UA groups indicate stronger bracket-to-composite adhesion. These findings suggest that UAs offer a reliable and efficient bonding method for composite restorations, particularly when minimizing clinical chair time and ensuring durable bracket retention are priorities.

ACKNOWLEDGMENT

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ABBREVIATIONS

BBF: Bracket Bond Failure

SBS: Shear Bond Strength

ARI: Adhesive Remnant Index

SB-UA: Single Bond Universal Adhesive

SB2-A: Single Bond 2 Adhesive

UA: Universal Adhesive

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Infrazygomatic Crest Mini-Implants (IZC) for Skeletal Class II Correction in Monozygotic Twins

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ABSTRACT

Objectives: To report the orthodontic treatment of monozygotic twins presenting Class II skeletal malocclusion, treated with extra-alveolar mini-implants in the infrazygomatic crest (IZC) and mass distalization of the maxillary teeth. **Methods:** Monozygotic twins (Patient 1, 11 years and 11 months, mixed dentition; Patient 2, same age, permanent dentition) presented with the main complaint of protruding teeth, convex facial profile, severe excess and Class II skeletal relationship. Comprehensive fixed orthodontic appliances were bonded to both archwires. Stainless steel wires were inserted into the maxilla, and IZC mini-implants were installed bilaterally. An elastic chain delivering approximately 350 gf on each side was extended from the IZC units to the mesial hooks of the maxillary canines. The force's line of action was designed to pass directly through the maxillary center of resistance to prevent unwanted tilting or rotation of the occlusal plane. **Results:** Post-treatment clinical and cephalometric evaluations revealed successful correction of Class II skeletal malocclusion for a Class I ratio. Both patients achieved total overjet and overbite correction, optimal intercuspation with the molars and canines in Class I, and a significant reduction in ANB angle (4° in Patient 1 and 3.5° in Patient 2). Structural overlaps confirmed 3 mm of true distalization of the maxillary body molars without vertical impairment or adverse rotation of the occlusal plane, resulting in a balanced mesofacial biotype and a passive and competent lip seal. **Conclusions:** The integration of fixed orthodontic appliances with IZC mini-implants is a highly effective, predictable, and minimally invasive biomechanical approach to mass-correct sagittal skeletal discrepancies in growing individuals, ensuring excellent three-dimensional dental control and facial profile harmony.

Keywords: Orthodontic Anchorage Procedures; Malocclusion, Angle Class II; Twins, Monozygotic; Tooth Movement Techniques; Orthodontics

Conflict of Interest: None

INTRODUCTION

Malocclusions can be caused by genetic or environmental variations, and the specific contribution of each factor remains poorly understood.¹ Monozygotic twins share high genetic similarity and exhibit the same facial phenotype, meaning their skeletal and occlusal characteristics are expected to develop similarly. However, this is only partially true; twins demonstrate significant genetic heritability regarding cranial base and mandibular length, maxillary body size, and facial height. Conversely, tooth positioning is more heavily influenced by environmental factors.^{2,3,4} Therefore, identifying hereditary differences in skeletal and dental characteristics between twins with skeletal malocclusion can provide valuable data for growth prediction and orthodontic treatment planning.^{5,6}

Class II malocclusion involves an anteroposterior discrepancy between the maxilla and mandible that compromises dental occlusion, demonstrating a significant hereditary component.^{7,8} Therapeutic options vary widely, encompassing extraoral appliances,⁹ fixed distalizers,¹⁰ clear aligners,¹¹ intermaxillary elastics,¹² therapeutic extractions,¹³ miniplates,¹⁴ as well as inter-radicular and extra-alveolar infrazygomatic

crest mini-implants (IZC).^{15,16,17} For complex cases or patients past their active growth phase, surgical-orthodontic intervention becomes necessary.¹⁸

Extra-alveolar mini-implants represent a recent alternative for Class II malocclusion treatment, yet they have become one of the most effective mechanics for correcting this discrepancy. Among these, mini-implants placed in the infrazygomatic crest (IZC) are widely emphasized; their indications include enabling the en masse or individual distal movement of maxillary teeth, depending on the specific characteristics of the malocclusion. These devices are inserted between the maxillary first and second permanent molars at an angle of approximately 70° relative to the occlusal plane. The IZC typically feature a 2-mm diameter, a transmucosal profile ranging from 4 to 6 mm, and a thread length of 10, 12, or 14 mm.¹⁹ Because they are anchored in a region of high bone density, they tolerate the application of higher orthopedic forces, specifically between 220 and 340 gF.¹⁵

Therefore, the aim of this study was to report the orthodontic treatment of monozygotic twins presenting with Class II skeletal malocclusion, managed with IZC and en masse distalization of the maxillary teeth.

CASE REPORT

Diagnosis

The monozygotic twins, Patient 1 (SFSR) and Patient 2 (EFSR), presented for orthodontic evaluation at 11 years and 11 months of age with a chief complaint of protruding teeth. Clinical soft-tissue analysis showed a convex profile, a reduced lower third of the face, and lip incompetence in both siblings. Notably, Patient 1 exhibited forced lip competence during closure (Figure 1).

Occlusal analysis demonstrated that both twins shared a Class II, Division 1 molar relationship, Class II canine fields, severe overjet, and mild anteroinferior crowding. Vertically, Patient 1 presented a moderate overbite, while Patient 2 displayed a deep bite. Maxillary and mandibular arch widths were adequate in both subjects (Figure 1).

Patient 1 presented with mixed dentition, characterized by the presence of second deciduous molars, with teeth UR5, UL5, LR5 and LL5 intraosseous and at Nolla stage 7 (one third of the root formed) (Figure 2A). In contrast, Patient 2 exhibited permanent dentition (Figure 2B). Cephalometric analyses revealed similar characteristics between the monozygotic twins: a skeletal Class II malocclusion, a balanced vertical growth pattern, and proclined maxillary and mandibular incisors relative to their respective skeletal bases, resulting in a convex soft-tissue and straight skeletal profile (Figure 3 and Table 1). Both subjects still possessed active facial growth potential.

Figure 1.

Initial extraoral and intraoral photographs. A-H: Patient 1; I-P: Patient 2.

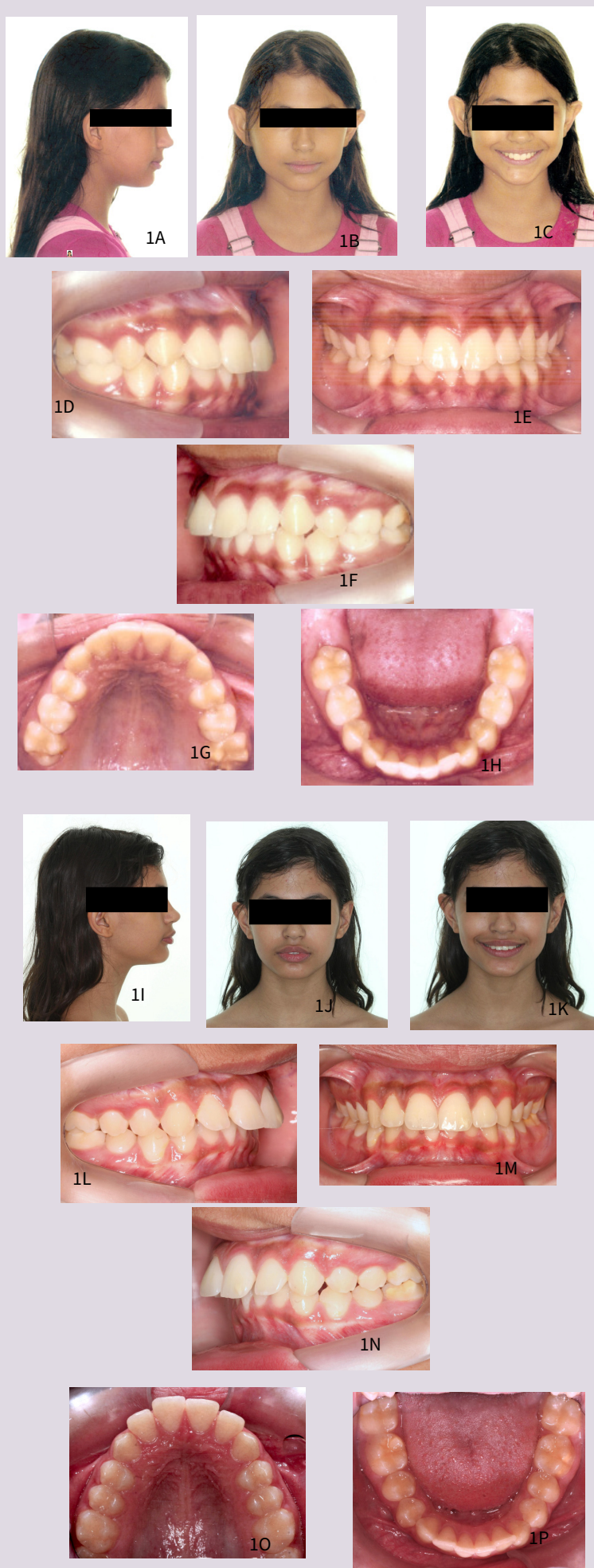
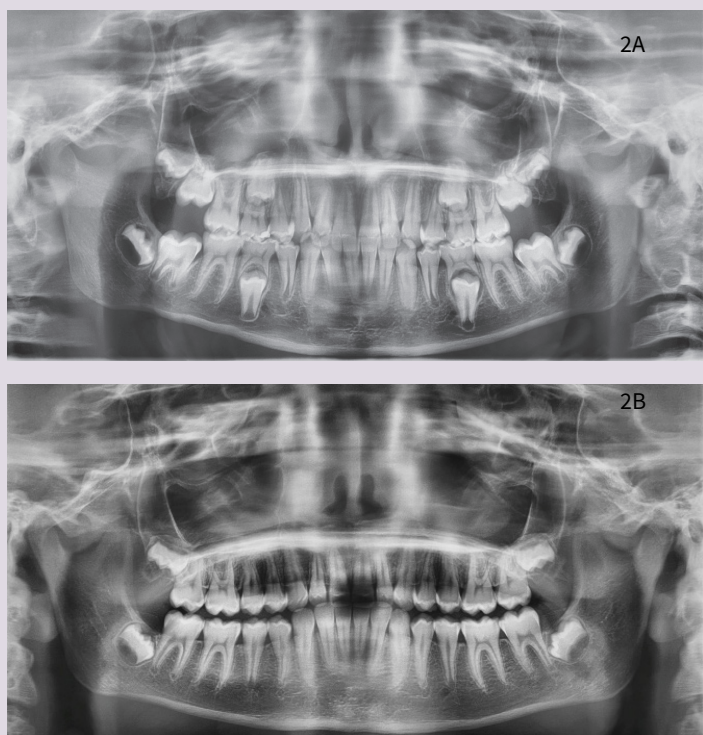
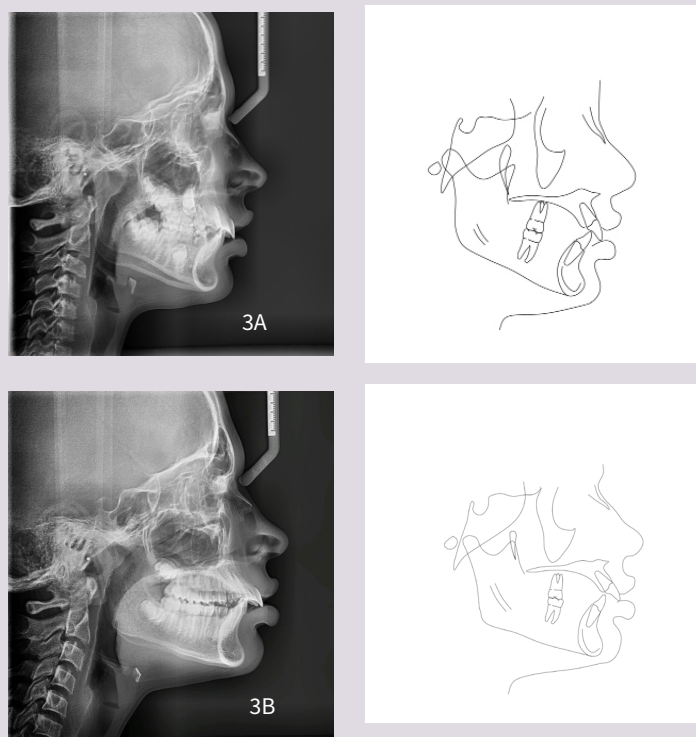


Figure 2.

Initial panoramic radiographs. A- Patient 1; B- Patient 2.

**Figure 3**

Initial panoramic radiographs. A- Patient 1; B- Patient 2.

**Table 1**

Cephalometric measurements before (A) and after (B) orthodontic treatment of monozygotic twins.

Measure Group	Cephalometric Measurement	Default Value (Normal)	Initial (A)	Patient 1 (SFSR) Final (B)	Δ (A - B)	Initial (A)	Patient 2 (EFSR) Final (B)	Δ (A - B)
Skeletal Pattern	SNA	82°	83°	80,5°	-2.5°	84,5°	82°	-2.5°
	SNB	80°	78°	79.5°	+1.5°	79°	80°	+1.0°
	ANB	2°	5°	1.0°	-4°	5,5°	2°	-3.5°
	Wits	♀ 0 ±2mm / ♂ 1 ±2mm	2 mm	0 mm	-2mm	1,5 mm	-0,5 mm	-2mm
	Convexity Angle	0°	4°	1°	-3°	3°	-1°	-4°
	Eixo Y	59°	65°	65°	0	63°	64°	+1
	Convexity Angle	87°	85°	85,5°	+0.5°	90°	86°	-4°
	SN.GoGn	32°	30°	33°	+3°	27°	29°	+2°
Dental Standard	FMA	25°	26°	27,5°	+1.5°	24°	23,5°	-0.5°
	IMPA	90°	100°	101°	+1°	99,5°	106°	+6.5°
	U1.NA	22°	28°	28.5°	+0.5°	33°	31°	-2°
	U1-NA	4 mm	4,5 mm	4 mm	-0.5mm	7 mm	6 mm	-1mm
	L1.NB	25°	29°	31°	+2°	29,5°	34°	+4.5°
Profile	L1-NB	4 mm	5 mm	5,5 mm	+0.5mm	4,5 mm	6 mm	+1.5mm
	1 - 1 Interincisal Angle	130°	118,5°	121°	+2.5°	112,5°	113°	+0.5°
	1 - APog	1 mm	2,5 mm	3 mm	+0.5mm	9,5 mm	7 mm	-1.5mm
	Upper lip - S-line	0 mm	0,5 mm	0 mm	-0.5mm	2,5 mm	-0,5 mm	-3mm
	Lower Lip - S Line	0 mm	1,5 mm	0,5 mm	-1mm	2,5 mm	2 mm	-0.5mm

Treatment Goals

The initial treatment objectives differed between the monozygotic twins, given that Patient 1 still retained their second deciduous molars. Consequently, at the family's request and to facilitate the logistics of appointment scheduling, the onset of orthodontic treatment was postponed to allow both patients to undergo therapy simultaneously.

Once Patient 1's deciduous teeth exfoliated and the first and second premolars, alongside the second molars, fully erupted (Figure 4), active orthodontic treatment commenced. The treatment goals for both monozygotic twins were now: correcting the skeletal Class II malocclusion, reducing overjet and overbite, leveling and aligning the maxillary and mandibular dentitions, establishing Class I molar and canine relationships, and achieving an adequate functional occlusion.

Treatment options

Various biomechanical approaches were considered to achieve the treatment objectives for the twins during the permanent dentition stage:

1. Clear aligners (CA) with sequential distal movement planning of the maxillary posterior teeth associated with Class II intermaxillary elastics or supported by IZC mini-implants.
2. Fixed orthodontic therapy combined with a KloeHN cervical headgear (KHG). This mechanics would redirect growth, distalize molars, and correct the skeletal Class II relationship, while fixed appliances would achieve leveling and alignment, resolve mandibular mild anterior crowding, flatten the curve of Spee, and correct both overjet and overbite.
3. Comprehensive fixed orthodontic appliances involving mechanical distalization of the maxillary posterior teeth via Class II intermaxillary elastics, supported by a sliding jig, open-coil springs, or directly engaged on the archwire. Again, the fixed appliances would serve to align and level the arches, resolve mandibular mild anterior crowding, flatten the Spee curve, and correct both overjet and overbite.
4. Fixed appliance therapy encompassing extractions of the maxillary first premolars (UR4 and UL4), subsequent retraction of the canines and incisors, and case finishing.
5. Fixed appliance therapy utilizing IZC or interradicular mini-implants for segmental maxillary posterior distalization, combined with elastics or open-coil springs activated via a sliding jig.
6. Comprehensive fixed orthodontic appliances involving en masse distalization of the maxillary dentition, utilizing IZC with elastics or open-coil springs extended from the IZC heads to the brackets of the maxillary canines.

Treatment plan and mechanics employed

After evaluating the case and discussing the treatment options with the family, comprehensive fixed orthodontic appliances combined with IZC for en masse maxillary distalization was selected for both patients (Option 6). The

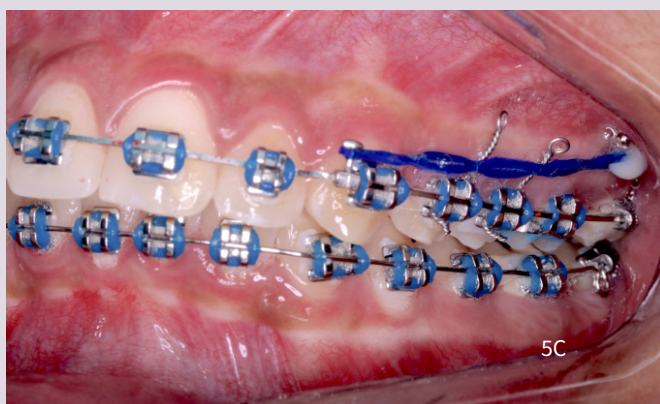
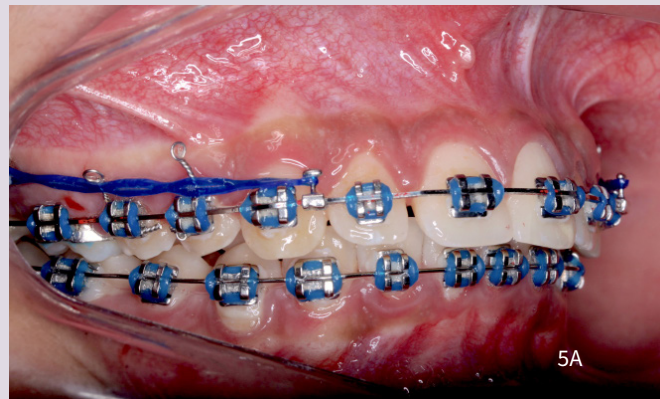
Figure 4.

Panoramic X-ray of Patient 1 after eruption of the second premolars.



Figure 5.

Initiation of maxillary arch distalization mechanics utilizing an elastic chain supported by infrazygomatic crest mini-implants (IZC) and an anterior traction hook positioned between maxillary lateral incisor and canines. To mitigate the risk of soft-tissue trauma caused by direct contact with the active elastic chain, Kobayashi tie wires were adapted to the maxillary premolar brackets.



other treatment plans were rejected for various reasons, including the unfavorable esthetics of the KHG, the patients' and family's refusal of tooth extractions, the high financial cost of CA, and the prolonged treatment time associated with sequential tooth-to-tooth distalization in the maxillary arch.

Fixed orthodontic appliances were bonded in both the maxillary and mandibular arches, utilizing brackets and tubes. In the maxillary arch, a sequence of 0.012-in, 0.014-in, 0.016-in, and 0.018-in nickel-titanium archwires followed by a 0.018 × 0.025-in stainless steel archwire was engaged for alignment and leveling. On this latter working wire, IZC mini-implants were installed bilaterally in the right and left infrazygomatic crests. An elastic chain was extended from each IZC unit to the mesial hooks of the maxillary canines, delivering approximately 300 gF per side (Figure 5). The line of action of the force generated by the elastic chain passed through the maxillary center of resistance (CRes), maintaining or making minor changes in the overbite. To allow the line of force to pass over the maxillary center of resistance, a short hook was placed on the archwire between teeth UR4 and UR3, and another between teeth UL3 and UL4. The IZC mini-implants were placed more superiorly between teeth UR6 and UR7, and UL6 and UL7. The final correction of overbite was achieved at the final of the leveling phase (Figure 6). With the force passing through the CRes of the maxilla, there is no rotation of the occlusal plane, as the center of rotation (CRot) is located at infinity. As the distal movement of the maxillary posterior teeth progressed, temporary diastemas developed within the anterior teeth. Consequently, an elastic chain was engaged from tooth UR6 to tooth UL6 to close these spaces and complete the overall correction of the malocclusion (Figures 6 and 7).

Alignment and leveling of the mandibular arch followed a slightly different sequence. It progressed through 0.012-in and 0.014-in nickel-titanium wires, followed by 0.018 × 0.025-in, and 0.020-in stainless steel archwires, combined with interproximal enamel reduction (stripping) and tie-back mechanics, leveling, and Class II correction. Finally, 0.019 × 0.025-in stainless steel archwires were engaged in both arches, incorporating ideal torques and finishing bends tailored for optimal intercuspation and detailing (Figure 8). At the end of treatment, a Begg appliance retainer was delivered for the maxillary arch with instructions for 2 years of wear, while a straight canine-to-canine fixed lingual retainer (0.7-mm wire) bonded exclusively to the canines was adapted to the mandibular arch.

Figure 6.

Schematic drawing illustrating the biomechanical system for correcting skeletal Class II malocclusion. (A) Initial malocclusion and mechanics of distal movement utilizing an elastic chain supported by an infrazygomatic crest mini-implant (IZC) and an anterior traction hook positioned between maxillary lateral incisor and canines, applying a force vector of 350gf per side. Distal translation of the maxillary arch occurs without tipping of the occlusal plane because the line of action of the force passes directly through the maxillary center of resistance (CRes); (B) Expected clinical outcome and therapeutic goal achieved through this mechanics.

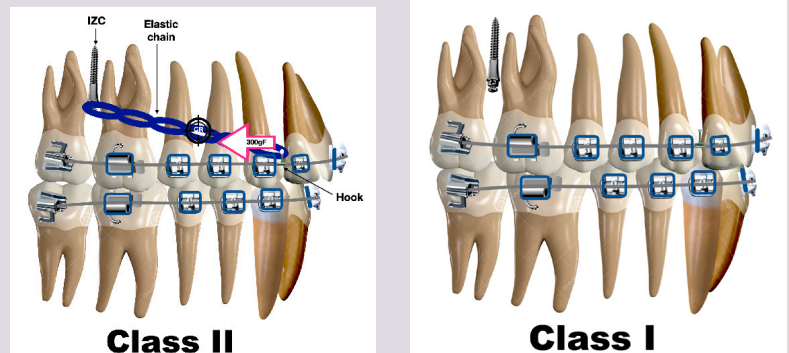


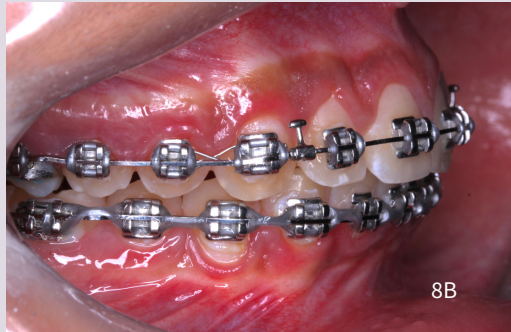
Figure 7.

Progress after 6 months of active biomechanics, demonstrating the successful correction of both the molar and canine relationships. An orthodontic elastic chain extending from tooth UR6 to tooth UL6 was incorporated into the mechanical system to close the diastemas that developed as a consequence of the distal translation of the maxillary posterior teeth.



Figure 8.

Stainless steel archwires for the finishing stage (0.019 x 0.025-in).



RESULTS

Significant facial changes were observed in both twins, successfully fulfilling the primary objective of correcting the skeletal Class II malocclusion. There was a noticeable reduction in profile convexity alongside the achievement of passive lip seal, without significant changes in vertical facial proportions. The dentitions were completely aligned and leveled, with full correction of the overjet and overbite. Class I molar and canine relationship was established, resulting in adequate intercuspation (Figure 9).

Functional occlusal evaluation at the end of treatment confirmed the establishment of adequate lateral and protrusive guides, along with simultaneous bilateral contacts in centric occlusion. Final panoramic radiographs demonstrated excellent root parallelism and showed the developing third molars approaching eruption (Figure 10).

Cephalometrically, a skeletal Class I relationship was achieved, accompanied by a significant reduction in the ANB angle and appraisal WITS. The balanced growth pattern was successfully maintained, with both patients

Figure 9.

Final extraoral and intraoral photographs. A-H: Patient 1; I-P: Patient 2.

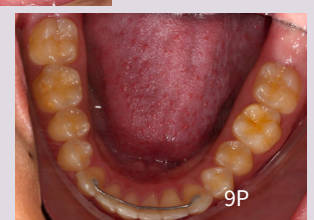
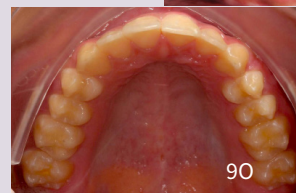


Figure 10.

Final panoramic radiographs. A- Patient 1; B- Patient 2.

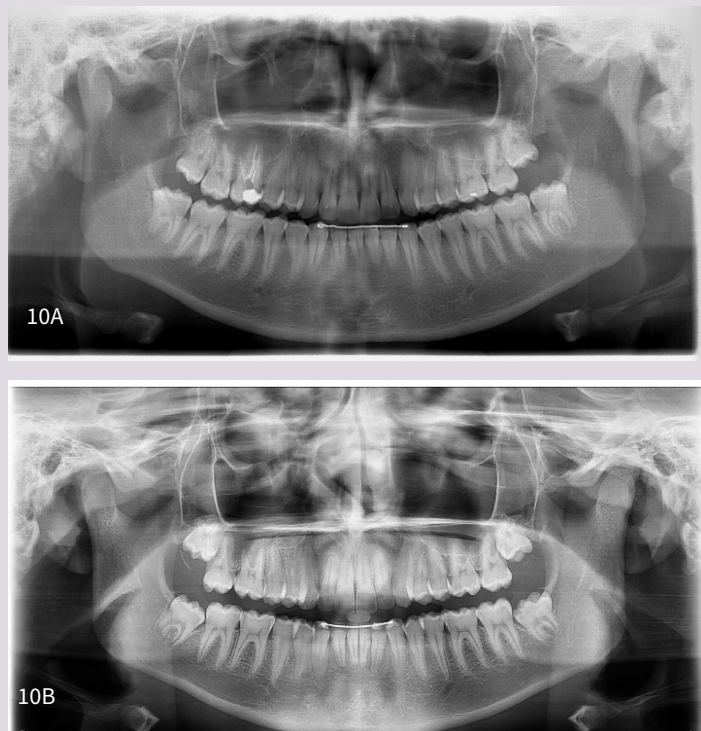


Figure 11

Final cephalometric radiographs and tracings. A and B- Patient 1; C and D- Patient 2.

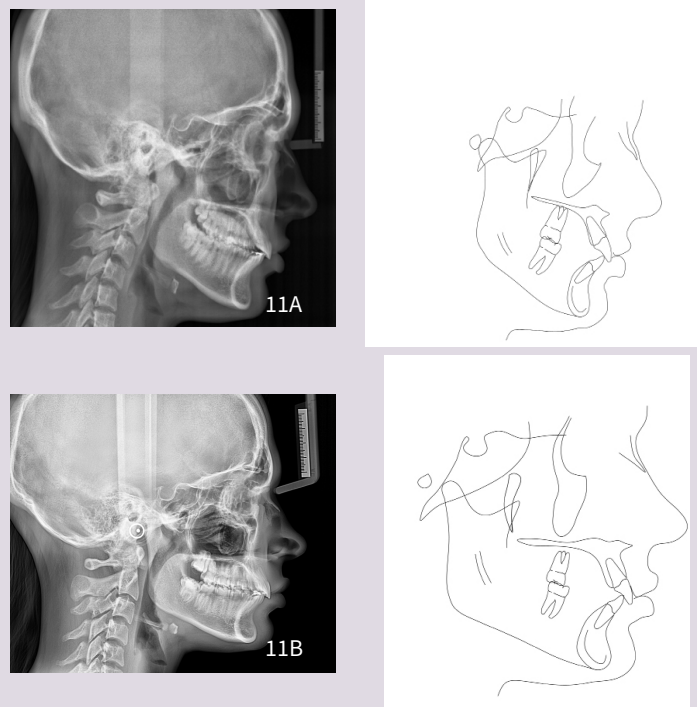
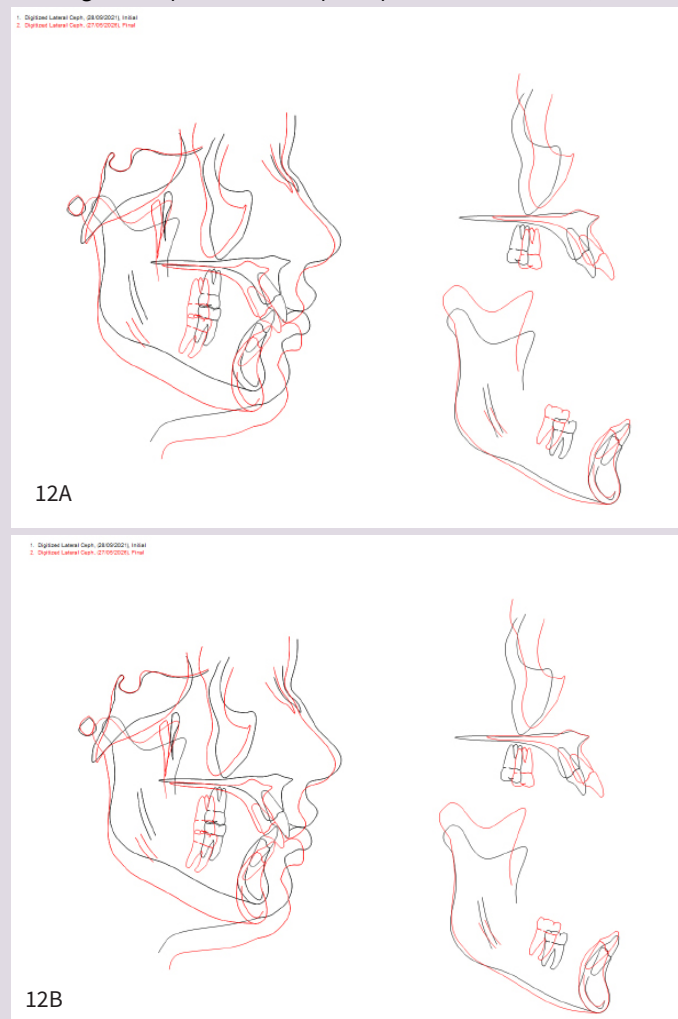


Figure 12

Total and regional cephalometric superimpositions. A Patient 1; B- Patient 2.



retaining their original mesofacial biotype. Dentally, the upper and lower incisors showed a slight increase in axial inclination and protrusion (Figure 11 and Table 1). Total cephalometric superimposition was performed at the cranial base—specifically along the “S-N” line, registered at point “S”—to evaluate global changes resulting from treatment with mini-implants inserted in the infrazygomatic (IZ) crest. Partial superimpositions were performed at the anterior nasal spine (maxilla) and the mandibular symphysis (mandible). The partial superimpositions described above were intended to evaluate dentoalveolar changes. The total superimpositions demonstrated a clockwise mandibular rotation, especially in Patient 1, with a minimal negative impact on the vertical skeletal configuration. Skeletal Class II correction was heavily driven by a combination of forward maxillary growth restriction and anterior mandibular displacement. Partial maxillary superimposition verified distal movement (Patient 2) and slight extrusion of the first molars (both patients), along with an increase in the axial inclination and a minor retrusion of the maxillary incisors in both patients. Partial mandibular superimpositions captured molar extrusion in both patients with a compensatory increase in the axial inclination of the lower incisors in twin patients. However, in Patient 2 there was a retrusion of incisors (Figure 12). The facial profile became concave in Patient 1, and the concavity already present in Patient 2 at the start of treatment worsened by the end of treatment. It is important to highlight that the profile concavities observed cephalometrically did not compromise the patients’ facial aesthetics.

DISCUSSION

Although identical twins possess a monozygotic genetic background, environmental influences can modulate craniofacial development and phenotypic expression, leading to different malocclusions.¹³ Nevertheless, in the absence of significant environmental variance, occlusal traits remain remarkably homogeneous among monozygotic twins.^{20,21} Correspondingly, the twins evaluated in this study presented with near-monozygotic skeletal Class II discrepancies (ANB = 5.0° and 5.5° for Patients 1 and 2, respectively) and presented highly analogous morphological traits, characterized by a Class II molar relationship, severe overjet, and similar dental crowding.

Patients presenting with a skeletal Class II malocclusion who exhibit significant active growth potential can generally be managed through two primary orthopedic approaches: restriction of forward maxillary translation, acceleration of mandibular advancement or both treatments. Conversely, in patients presenting with advanced skeletal maturation or late adolescence, the clinical spectrum shifts, and alternative therapeutic strategies must be considered. These traditional modalities include non-extraction maxillary posterior distalization utilizing intraoral distalizers or temporary anchorage devices (TADs) paired with open-coil springs, sliding jigs, or intermaxillary elastics. Permanent dental extractions to camouflage the skeletal discrepancy or, in cases involving severe skeletal disharmonies, combined orthodontic-orthognathic surgery at the cessation of craniofacial growth.

Recent studies have shown promise in that Class II skeletal malocclusions can be predictably corrected using the IZC technique. Rosa et al.²² in a study evaluating 25 Class II patients treated with IZC, reported an average dental Class II correction characterized by 4mm of molar distalization, 1.2mm of intrusion, and 11.28° of distal tipping of the maxillary molar crowns, alongside mean reductions in overjet (3.6mm) and overbite (2.4mm). In the present case report, certain findings were consistent with their outcomes, whereas others showed minor discrepancies. Specifically, our patients achieved successful Class II to Class I molar correction via 3mm of molar distalization. However, this occurred through true bodily movement without significant molar intrusion (Figure 12B). Both twins demonstrated highly significant improvements in overjet and overbite measurements, reaffirming that the use of IZC can produce highly satisfactory sagittal results.

One of the most critical issues discussed in the literature regarding maxillary molar distalization concerns undesirable vertical adverse effects, which are commonly associated with traditional mechanics such as extraoral headgear and functional activators. Because the force is applied directly to the molars, certain appliances make it challenging to control the vertical dimension of the force vector. This limitation frequently induces unwanted

molar extrusion or intrusion, which often compromises the patient's vertical skeletal relationship. To avoid these adverse effects, it is crucial to control the rotation of the occlusal plane. With the use of IZC for Class II correction, there are three options for the line of action of the force,¹⁵ which are directly related to the maxillary CRes located between the premolars at the level of the third of the root closer to the dental crown:

1. Line of action of the force passing directly through the CRes results in little or no rotation of the occlusal plane. The CRot is located in the infinite.
2. Line of action of the force passing above the CRes: promotes a counterclockwise rotation of the occlusal plane, generating relative intrusion of the incisors and relative extrusion of the molars. The CRot is located below the CRes of the maxilla, towards the crowns of the upper teeth.
3. Line of action of the force passing below the CRes: promotes a clockwise rotation of the occlusal plane, causing relative extrusion of the incisors and relative intrusion of the molars. The CRot is located above the CRes of the maxilla, towards the roots of the upper teeth.

The greater the distance between the line of action of the force represented by the traction elastic and the center of resistance (CRes) of the maxilla, the greater the effects on the occlusal plane i.e., the greater the clockwise or counterclockwise rotation. These changes in the occlusal plane can be strategically determined by the position of the anterior support hook and the height of insertion of the IZC.

In the present clinical case, the selection of the biomechanical design efficiently neutralized these vertical risks. The line of action of the force established from the high insertion site of the mini-implant in the infrazygomatic crest (IZC) toward the anterior hook positioned on the mesial aspect of the maxillary canines was planned to pass directly through the CRes of the maxilla.¹⁵ As a direct result of this vector control, a pure translational bodily movement of the entire maxillary dentition was achieved, without undesirable tipping of the occlusal plane or extrusive effects on either the anterior teeth or the molars (Figures 6 and 12). It is important to note that the maxillary teeth were retracted en-masse, resulting in the correction of the overjet and Class II malocclusion (Figures 6, 7, and 8).

This biomechanical improvement had a direct impact on the twins' facial growth pattern. Although the total overlap indicated a subtle tendency toward clockwise rotation of the mandible, the patients' facial morphological type remained mesofacial at the end of treatment without vertical compromise. This stability supports the clinical guidelines of Roberts et al.²³, who advocate the use of skeletal anchorage in the maxilla as the method of choice for counteracting extrusive forces and controlling the vertical component during mass retraction. In contrast, the FMA angle increased by 1.5° in Patient 1 and decreased by 0.5° in Patient 2. In Patient 1, the FMA angle followed the increase in the SN.Go.Gn angle. However, Patient 2's response was quite different. This contrast in results is

due to the difference in facial morphological type between the patients: Patient 1 is mesofacial, and Patient 2 is brachyfacial. Despite being monozygotic twins, patients may exhibit distinct muscular patterns, which directly impacts posterior tooth extrusion and/or mandibular rotation in response to treatment.

At the same time, the facial and soft-tissue integumentary changes observed in both patients evidenced the remarkable orthopedic potential of this technique when applied during stages of active growth. Initially, both twins exhibited prominent convex facial profiles accompanied by lip incompetence. Following en masse distalization and the subsequent controlled retraction of the maxillary incisors, a clear structural improvement of the upper lip was achieved, leading to the reestablishment of a completely competent, passive lip seal (Fig. 9 and Table 1). The decrease in soft-tissue facial convexity and the resulting harmony gained in the lower facial third reinforce that retraction anchored by IZC does not merely reorganize dentoalveolar relationships.

The dental results reported by Rosa et al.²² were encouraging. However, the anteroposterior skeletal response did not match this dentoalveolar success, as evidenced by the discrepancy between the ANB angle and the Wits appraisal linear measurement. In their study, the authors observed a mean increase in the ANB angle of $+0.75^\circ$ and a concurrent decrease in the Wits appraisal of -1.65 mm. Conversely, in the present case report, the ANB angle was drastically reduced, reaching an ideal value of 1° and 2° for Patients 1 and 2, respectively, representing a clinical reduction of 4° in Patient 1 and 3.5° in Patient 2. Similarly, the Wits appraisal decreased by 2mm in each patient. This skeletal correction occurred through the orthopedic restriction of forward maxillary growth combined with a favorable anterior mandibular growth response (Fig. 12). These outcomes validate and support the clinical utilization of IZC in patients whose skeletal Class II discrepancy is primarily driven by maxillary prognathism, but who concurrently benefit from forward mandibular projection. This divergence in outcomes between the study by Rosa et al.²² and the present work may be attributed to differences in skeletal and chronological age between the sample cohorts. Specifically, a more advanced age prevailed among the patients in the aforementioned prospective study compared to our patients (13y 6m versus 11y 11m, respectively). Consequently, these findings highlight a clear clinical tendency: significantly superior anteroposterior skeletal outcomes can be achieved when IZC mechanics are implemented in younger patients during early adolescence, when substantial active growth potential remains available. Despite the positive results reported in the cases, a limitation of this work is the lack of long-term evaluation to confirm the stability of the correction. This was not possible because the twins had just finished treatment.

After discussing various aspects of treating Class II malocclusion using mini-implants in the infrazygomatic crest (IZC) region and evaluating the technique in

monozygotic twins, it is important to compare this method with others found in the literature. There are other treatment options with the same objective. When comparing the correction of this malocclusion via premolar extraction (maxillary or both maxillary and mandibular) versus mechanics using IZC mini-implants, the latter proves to be more conservative. However, extraction guarantees a real and immediate gain in arch space for the distalization of canines and incisors. Little is known about the stability of IZC treatments due to a scarcity of long-term studies. In contrast, the stability of correction via extraction is well established.¹⁷ In some situations, the IZC mini-implant may be lost, making distal movement of the upper teeth impossible or substantially delaying treatment until a new mini-implant can be placed. Uribe et al.²⁴ reported a failure rate of 21.8% after evaluating 55 placed IZC mini-implants; this rate represents one of the technique's disadvantages. Other treatment options for distalizing upper teeth include the use of intermaxillary elastics and springs (with or without sliding jig support). However, compared to IZC mini-implants, these methods are less comfortable and entail side effects such as anchorage loss, reliance on patient compliance, and unwanted movement of anchor teeth.²⁵ Thus, although IZC mini-implants are efficient for treating Class II malocclusion, difficulties can arise during treatment; many of their effects remain unknown, making this topic an open book waiting to be written.

CONCLUSION

The combination of fixed orthodontic appliances with IZC proved to be a highly effective and predictable biomechanical alternative for the simultaneous correction of dental and skeletal Class II malocclusions in monozygotic twins. This treatment protocol allowed for excellent three-dimensional control of tooth movement, resulting in a significantly improved soft-tissue facial profile and the reestablishment of sagittal skeletal balance during active craniofacial growth. Some dental and skeletal responses differed between monozygotic twins, reinforcing that, despite genetic components, treatment effects can vary depending on muscular characteristics and the specific features of the malocclusion.

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Recent Advances in Biocompatible Shape Memory Polymers for Craniofacial and Orthodontic Applications: From Material Design to 3D/4D Printing

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ABSTRACT

Shape memory polymers (SMPs) are stimuli-responsive biomaterials with potential for patient-specific craniofacial and orthodontic applications. This review summarizes advances in biocompatible SMP design, functionalization, and 3D/4D printing, emphasizing adaptive devices and regenerative scaffolds. Current evidence, translational limitations, and priorities for clinical research are critically discussed.

Keywords: Shape memory polymers; biocompatible polymers; orthodontics; craniofacial applications; 3D printing; 4D printing; biomaterials

Conflict of Interest: None

INTRODUCTION

Shape memory polymers (SMPs) are smart polymeric materials capable of recovering a programmed permanent shape after exposure to an appropriate stimulus. Depending on polymer chemistry and network architecture, activation may be achieved by temperature, light, magnetic fields, pH, moisture, or other environmental cues. Their low density, large recoverable deformation, and tunable mechanical properties have made SMPs attractive for biomedical devices, tissue engineering, and controlled drug delivery.¹⁻⁴

The shape-memory effect generally depends on a stable network that defines the permanent configuration and a reversible switching segment or phase that permits temporary-shape fixation and subsequent recovery. The relevant transition temperature or other activation threshold must be matched to the intended application. For biomedical use, this requirement is particularly important because excessive activation temperatures, uncontrolled degradation, or insufficient mechanical stability can limit clinical feasibility.^{1,4,10,11}

Biocompatible and biodegradable SMPs have received increasing attention for temporary implants and regenerative applications. Poly(lactic acid) (PLA), polycaprolactone (PCL), polyurethane-based systems, and bioinspired polymers have been investigated with different combinations of mechanical strength, degradation behavior, and shape-recovery performance. However, biocompatibility is material- and formulation-dependent and should not be assumed solely from the polymer class.^{2,3,7,11,12}

Additive manufacturing has expanded the design space of SMP-based devices by enabling patient-specific geometries. Three-dimensional (3D) printing can fabricate

complex structures, while four-dimensional (4D) printing incorporates programmed time-dependent or stimulus-responsive shape change. These capabilities are particularly relevant to craniofacial engineering, where anatomy is highly individualized and adaptive materials may eventually support minimally invasive delivery, tissue regeneration, and personalized device fabrication.^{5,6,16,17}

The present review summarizes recent developments in biocompatible SMPs from material design and synthesis through 3D/4D fabrication and biomedical applications. Particular emphasis is placed on craniofacial and orthodontic relevance, while distinguishing established evidence from emerging or preclinical concepts.

2. MATERIAL DESIGN OF BIOCOMPATIBLE SMPs

Material selection for biomedical SMPs requires simultaneous consideration of shape-recovery behavior, transition temperature, mechanical performance, degradation, sterilization, manufacturability, and biological response. No single polymer family is optimal for all applications.^{2,4,6,11,15}

2.1. Polyurethane-Based SMPs

Polyurethane SMPs are attractive because their hard and soft segments can be tailored to modify transition temperature, elasticity, and recovery behavior. Systems designed around physiological temperatures may be useful for devices that are deployed in a compact configuration and recover after implantation. Nevertheless, polyurethane chemistry is highly variable, and claims of long-term biocompatibility or biodegradability should be supported by formulation-specific evidence.^{7,11}

2.2. Biodegradable SMPs

PLA- and PCL-containing systems are important candidates for temporary biomedical structures because their degradation can be engineered through molecular weight, crystallinity, copolymerization, blending, and processing. Their degradation products and rates depend on polymer composition and conditions; therefore, simplified statements that a polymer family always produces a single specific metabolite should be avoided. Blending and copolymerization can modify both mechanical properties and degradation kinetics, which may be advantageous for tissue-engineering scaffolds.^{2,3,11}

2.3. Bioinspired SMPs

Bioinspired systems based on or incorporating materials such as chitosan, collagen, and gelatin may provide biological functionality in addition to shape-memory behavior. Chemical crosslinking or other network-forming strategies can improve mechanical stability, but may also alter swelling, degradation, cytocompatibility, and stimulus response. These

trade-offs are particularly important when considering craniofacial tissue engineering.^{8,9,12}

2.4. Stimuli-Responsive Design

Thermal activation is attractive for biomedical applications because it can be engineered around a defined transition temperature. Light- and magnetic-responsive systems can provide remote actuation but introduce additional requirements related to penetration depth, energy delivery, nanoparticle safety, and clinical equipment. pH- and enzyme-responsive systems may offer greater physiological specificity for selected applications. The most clinically relevant stimulus is therefore application-dependent rather than universally superior.^{4,6,15}

3. SYNTHESIS AND FUNCTIONALIZATION STRATEGIES

Common synthesis routes include ring-opening polymerization, polycondensation, and radical or photopolymerization. Processing conditions influence molecular weight, crosslink density, crystallinity, transition temperature, and mechanical behavior. Functionalization can further modify water uptake, cell interaction, degradation, or stimulus responsiveness.^{2,4,11}

3.1. Synthesis Techniques

Ring-opening polymerization is widely used for aliphatic polyesters such as PLA and PCL. Polycondensation is important for polyurethane and related networks, while radical and photopolymerization are particularly useful for photocurable resins used in additive manufacturing. The selection of chemistry should be linked to the intended clinical environment and printing process.^{2,3,11}

3.2. Functionalization Approaches

Hydrophilic segments such as polyethylene glycol (PEG) can alter water uptake and biological interactions. Bioactive motifs such as RGD peptides may promote cell adhesion, while nanomaterials can modify mechanical, electrical, optical, or magnetic properties. These modifications may improve one functional parameter while adversely affecting another; therefore, multifunctionality should be evaluated as a balance rather than assumed to be universally beneficial.^{3,7,12}

3.3. Nanoparticle Integration

Stimuli-responsive nanoparticles can provide remote activation of SMP composites. Magnetic particles may enable magnetic-field actuation, whereas photothermal particles can support light-mediated activation. Translation to clinical use requires careful evaluation of particle retention, release, toxicity, sterilization, imaging compatibility, and the reproducibility of the composite.^{6,12,15}

4. 3D AND 4D PRINTING OF SMPs

Additive manufacturing is particularly relevant to craniofacial and orthodontic applications because digital workflows can translate patient-specific anatomical data into customized devices. Fused deposition modeling (FDM), stereolithography (SLA), digital light processing (DLP), and

related methods offer different combinations of resolution, material compatibility, speed, and post-processing requirements. For SMPs, printing parameters can also affect molecular orientation, residual stress, crosslinking, dimensional accuracy, and subsequent shape-recovery behavior.¹⁶⁻²¹

4.1. 3D Printing Techniques

FDM is suitable for selected thermoplastic SMPs, whereas SLA and DLP can produce high-resolution structures from photocurable formulations. Selection should consider the intended device, required resolution, mechanical loading, sterilization method, and biological exposure. For orthodontic use, additional considerations include intraoral aging, moisture, thermal cycling, force relaxation, wear, and material safety.^{16,17,20}

4.2. 4D Printing Innovations

4D printing extends additive manufacturing by programming a structure to undergo a controlled change after fabrication. In biomedical applications, this may permit deployment of a compact structure followed by expansion, bending, folding, or another predefined transformation. The concept is promising for adaptive scaffolds and minimally invasive devices, but most applications remain experimental and require validation of actuation reliability under clinically realistic conditions.^{5,6,16,17}

4.3. Craniofacial and Orthodontic Relevance

Recent orthodontic literature increasingly focuses on direct 3D-printed clear aligners and shape-memory materials. Tartaglia et al.¹⁸ described the current state and future possibilities of direct 3D printing for aligners, emphasizing improved accuracy, reproducibility, and force control. Narongdej et al.²⁰ systematically reviewed direct-3D printing technologies and concluded that clear aligner fabrication is rapidly evolving. Atta et al.²¹ evaluated a 3D printed shape-memory aligner material and reported substantial shape recovery at oral temperature, supporting the feasibility of 4D aligner concepts. Torkomian et al.²³ found that 3D-printed clear aligners may become a practical alternative to thermoformed aligners, although higher-quality evidence is still needed. Ebrahimi et al.²⁵ and Aafreen et al.²² further highlighted the emerging role of 4D printing and bio-smart materials in digital orthodontics and dentistry.¹⁸⁻²⁵

Potential applications include patient-specific orthodontic appliances, adaptive components, craniofacial scaffolds, and digitally fabricated structures for regenerative procedures. However, the terminology should be used carefully: not every 3D-printed orthodontic polymer is a true SMP. Shape-memory behavior requires a demonstrable programmed temporary state and stimulus-induced recovery; simple elastic rebound should not be labeled as a shape-memory effect.¹⁸⁻²⁵

5. BIOMEDICAL APPLICATIONS

Biocompatible SMPs have been investigated in minimally invasive devices, tissue engineering, drug delivery, and

soft robotic systems. The maturity of evidence varies substantially among these applications, and most advanced 4D concepts remain preclinical.^{2,3,6,12,15,17}

5.1. Minimally Invasive Devices

SMP-based stents, catheters, and other deployable structures can be introduced in a compact configuration and subsequently recover a functional shape. The potential advantage is reduced delivery size and procedural trauma. Translation requires reliable recovery under physiological conditions, fatigue resistance, secure deployment, and predictable long-term biological behavior.^{2,3,6,15}

5.2. Tissue Engineering and Craniofacial Regeneration

SMP scaffolds can combine structural support with programmed shape change and may therefore be useful when a scaffold must be delivered in a constrained configuration and subsequently conform to a defect. This concept is particularly relevant to craniofacial bone and cartilage regeneration. A bioactive self-fitting SMP scaffold has previously been investigated for cranio-maxillofacial bone defects, supporting the biological rationale for this application.^{8,9,17}

5.3. Drug Delivery

Shape change can be coupled to drug release, allowing physiological or externally delivered stimuli to alter device geometry or permeability. Temperature-, pH-, and magnetically responsive systems have been investigated. However, targeted drug delivery remains application-specific and should not be generalized to all SMP platforms.^{2,3,6,12}

5.4. Soft Robotics

SMP-based soft actuators may be useful in surgical or assistive devices because their compliance and programmable deformation can be exploited for controlled motion. Nevertheless, the relevance to routine orthodontic practice is currently indirect, and these applications should be presented as future-facing technology.^{6,12,16}

6. CHALLENGES, TRANSLATIONAL BARRIERS, AND FUTURE DIRECTIONS

The main barriers to clinical translation are not limited to material performance. They include reproducible manufacturing, sterilization, long-term biological safety, fatigue, degradation control, activation reliability, regulatory requirements, and the ability to demonstrate clinically meaningful benefit.^{6,16,17}

6.1. Scalability and Manufacturing Reproducibility

Advanced polymer synthesis and high-resolution additive manufacturing may be costly or difficult to scale. For patient-specific devices, reproducibility across batches and printers is essential.^{6,16,17}

6.2. Mechanical Durability and Functional Fatigue

Shape recovery should remain reliable after repeated deformation and under clinically relevant mechanical

loading. Long-term force relaxation, creep, wear, and fatigue are particularly important for orthodontic devices exposed to repeated intraoral loading.^{4,7,16,21}

6.3. Biocompatibility, Degradation, and Sterilization

Biocompatibility must be demonstrated for the complete formulation, including additives, residual monomers, nanoparticles, degradation products, and processing residues. Sterilization can alter polymer chemistry and shape-memory behavior and therefore requires validation.^{2,7,15,19,24}

6.4. Stimulus Delivery and Actuation Reliability

External heat, light, or magnetic fields may be difficult to deliver safely and uniformly in vivo. Physiological stimuli may be attractive, but they also require precise control to avoid premature or incomplete activation.^{4,6,15}

6.5. Digital Workflow and Patient-Specific Manufacturing

For orthodontic and craniofacial applications, integration with intraoral scanning, imaging, CAD/CAM, and additive manufacturing creates opportunities for personalization. At the same time, errors in segmentation, design, printing, post-processing, and material programming can propagate into the final device.¹⁸⁻²⁵

6.6. Regulatory and Clinical Validation

Future studies should move beyond proof-of-concept demonstrations toward standardized mechanical and biological testing, appropriate animal models, prospective clinical studies, and regulatory evaluation. Multidisciplinary collaboration between orthodontists, craniofacial surgeons, biomaterials scientists, engineers, and regulatory specialists will be essential.^{6,16,17,23-25}

7. FUTURE RESEARCH PRIORITIES FOR ORTHODONTICS AND CRANIOFACIAL CARE

Future work should prioritize clinically relevant questions rather than material novelty alone. Important directions include the development of patient-specific SMP appliances with reproducible force delivery, investigation of long-term intraoral aging and force relaxation, evaluation of biocompatibility and degradation under realistic oral conditions, and optimization of 3D/4D printing workflows for craniofacial defects. Comparative studies against established orthodontic polymers are needed to determine whether SMP-based systems provide clinically meaningful advantages.¹⁸⁻²⁵

Importantly, the current evidence supports SMPs as an emerging research platform rather than an established clinical standard. The most credible path toward adoption is therefore a staged progression from material characterization and benchtop testing to preclinical validation and well-designed clinical studies.

8. CONCLUSION

Biocompatible SMPs combine programmable shape change with tunable mechanical and biological properties, creating opportunities for adaptive biomedical devices

and regenerative scaffolds. Advances in 3D and 4D printing further enable patient-specific geometries, making these materials relevant to craniofacial and potentially orthodontic applications. Current evidence, however, remains heterogeneous and largely preclinical. Future research should focus on reproducible manufacturing, intraoral and physiological durability, biological safety, regulatory requirements, and comparative clinical outcomes before routine orthodontic adoption can be justified.^{1-6,8,9,17}

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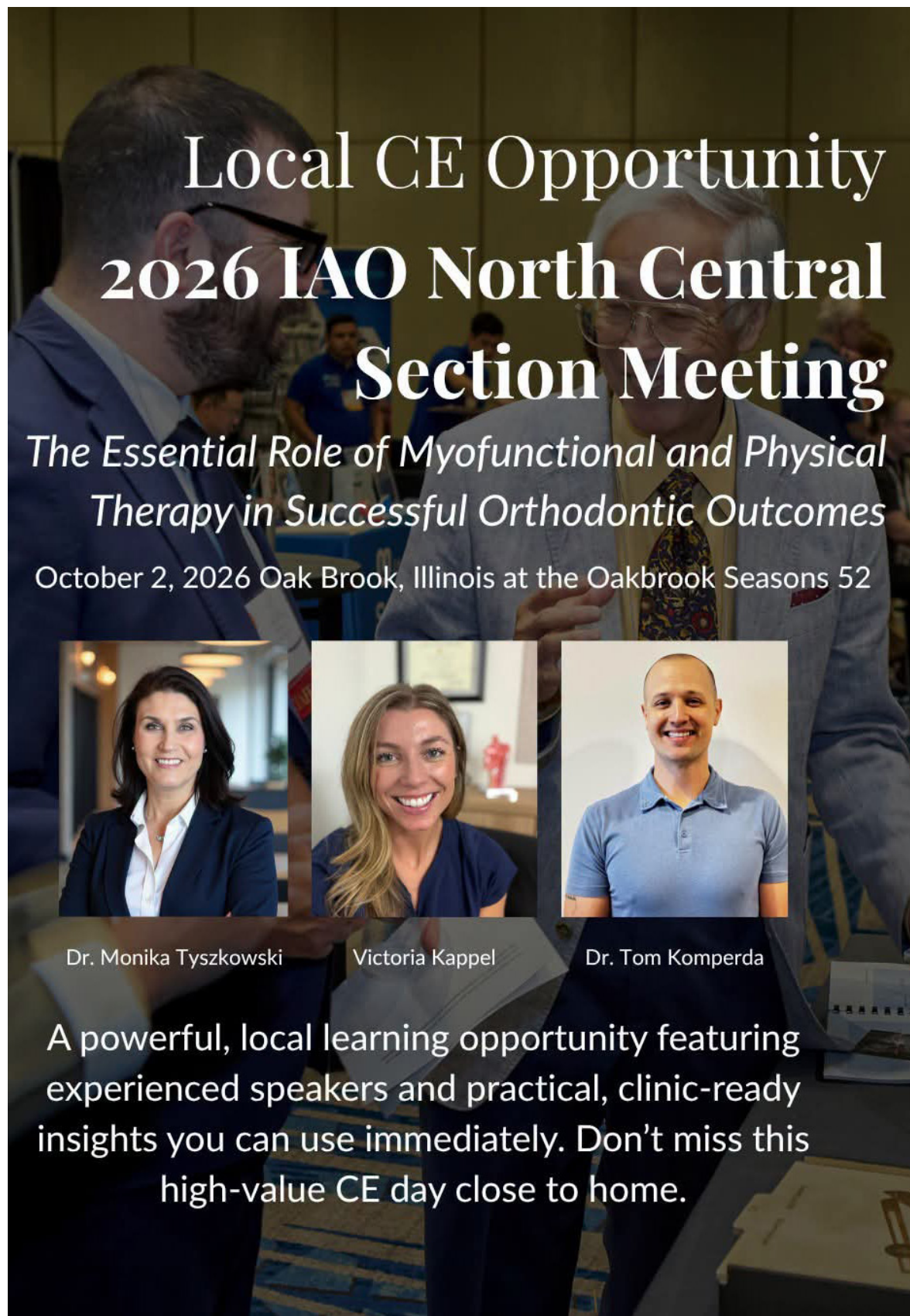
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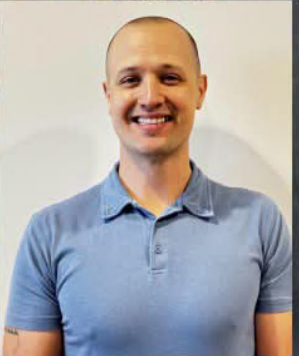
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Former Dean, Chair, and Program Director
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ABSTRACT

From a legal perspective, it is only because of the existence of a doctor patient relationship that a doctor is required to conform to a given standard of care. While this special relationship is easy to establish, it is difficult to terminate unless specific protocols are followed. If the steps to legally dismiss a patient from one's practice are not adhered to, the doctor may be found liable for having abandoned his patient.

Keywords: Formation and Termination of the Doctor Patient Relationship, Patient Abandonment

Conflict of Interest: None

Creating the Doctor-Patient Relationship

The relationship between the doctor and the patient is often viewed as a type of simple contract. As one court¹ noted:

Any time a doctor undertakes the treatment of a patient, [a]...consensual relationship of physician and patient is established... [The] doctor and patient enter into a simple contract, the patient hoping that he will be cured and the doctor optimistically assuming that he will be compensated.

In order for any doctor to owe any patient the obligation to adhere to a given standard of care, it can only be due to the existence of a doctor-patient relationship. In the Irvin case², the court noted that "[t]he existence of a duty of care is dependent on the existence of a doctor-patient relationship". As noted in McKinney³, this contractual relationship arises out of "...a consensual contract of employment, express or implied, under which the patient seeks medical assistance and the physician agrees to render treatment." To close the circle, the Osborne decision⁴ stated that "[t]he voluntary acceptance of the physician-patient relationship by the affected parties creates ...a contractual relationship between them."

It is incredibly easy to form a doctor-patient relationship. Generally, the minute you offer a professional opinion on which you expect the patient to rely, and upon which the

patient subsequently acts by relying on your statements, a doctor-patient relationship is formed. The venue is irrelevant. The relationship does not have to be formed in an office environment; for instance, it can be formed at a cocktail party, a school playground, etc. It doesn't matter if you examined the patient, nor does it matter if you charged a fee for providing your professional opinion. The offering of professional advice which the patient followed is sufficient.

TERMINATING THE DOCTOR-PATIENT RELATIONSHIP

Practitioners find that this relationship, while easy to form, is much more difficult to terminate. In 1975, Paul Simon told us that there were "50 Ways to Leave Your Lover". However, in orthodontics, there are only five ways to terminate the doctor-patient relationship. The first is when both parties agree to end it. This usually occurs when a patient is relocating and they need to find another practitioner to take over the treatment you started. There were no problems, everyone was happy, the patient just happens to be moving. As noted in the McGloin⁵ decision, "[w]hen a physician takes charge of a case, his employment continues until ended by mutual consent...".

The second way the relationship can end is when the patient is cured. The Weiss⁶ court succinctly noted that "[o]nce a physician has taken charge of a case, that relationship continues until... the medical situation becomes one in which the physician's services are no longer needed".

The third way it happens is when one of the "4D situations" arises. Those occurrences are 1) the displacement of the doctor from practice [fire, flood, natural disaster, etc.]; 2) the doctor or the patient dies; 3) the doctor becomes disabled; or 4) the doctor is done and is retiring from practice. As was noted in the Warwick⁷ decision

Where defendant, ...was obliged to leave the vicinity because of his own ill health, but left plaintiff in the charge of another physician who continued the treatment, the court held that there was no ground for a complaint of abandonment ...because of the change in doctors.

The fourth way to terminate the doctor-patient relationship occurs when the patient decides to unilaterally

terminate the doctor-patient relationship. In these situations, the patient is often dissatisfied with some administrative or clinical aspect of the practice or their treatment and decides to unilaterally leave the practice. As the Glenn⁸ court noted “[o]nce a physician has taken charge of a case, that relationship continues until ...the physician’s dismissal by the patient.”

Finally, we arrive at the real issue, the situation where the doctor has had enough and wishes to unilaterally sever the doctor-patient relationship but does not want to become exposed to a patient claiming that they were abandoned. Looking back at the Osborne⁴ case noted above, we can see that

The physician has a definite right to withdraw from the case provided he gives the patient reasonable notice so as to enable him to secure other medical attendance. Such a withdrawal does not constitute an abandonment.

So, what are the legally acceptable reasons that exist for a doctor to use as a basis for ending the doctor-patient relationship; and what is the protocol one must use to avoid a claim that the doctor abandoned his patient? As is true of any contract, each party entering such a relationship assumes certain rights, obligations, and duties (RODs). While the duties that doctors owe their patients are quite numerous, there are only six legally accepted RODs that patients owe their doctors; they are

- 1) patients will not dictate inappropriate treatment;
- 2) clinical instructions will be followed;
- 3) appointments will be kept;
- 4) fees for services rendered will be paid;
- 5) patients will be truthful regarding all valid clinical and administrative inquiries; and finally,
- 6) patients will conform to accepted modes of behavior.

Let’s look at these legally recognized RODs individually.

The Mathies case⁹ provides insight into a little discussed area of law. We are all aware of a patient’s autonomy but few of us recognize the opposite side of the coin, a practitioner’s autonomy. As noted by the court

[i]f a patient selects a course of treatment, even from among reasonable alternatives, which physician regards as inappropriate or disagreeable, [a] physician is free to refuse to participate and to withdraw from case.

You cannot allow the patient to dictate the course of therapy. If you believe what the patient wants is fine and you feel comfortable providing whatever that service happens to be, no problem. But, if you disagree for whatever reason, you cannot be forced or coerced by a patient to provide specious treatment. The George¹⁰ decision revealed that

...the patient voluntarily submitted himself to and insisted upon medical care. Simultaneously he sought to dictate to treating physicians a course of treatment amounting to medical malpractice. The patient may knowingly decline treatment, but he may not demand mistreatment.

The second legally recognized reason for dismissing a patient from one’s practice relates to patients who won’t follow the doctor’s instructions or directions. When a patient is acting in a manner that is detrimental to their best interests, and you are unable to rehabilitate their non-compliance issues, the Urrutia¹¹ decision informs us

... if a physician is ever justified in withdrawing when it is apparent that to do so may result in injury, it can only be where the patient obstinately refuses to follow the treatment prescribed.

Orthodontics, like many other branches of dentistry, carries some unique characteristics that are associated with rendering appropriate therapy; one of which is keeping regularly scheduled appointments. Force applications, wire integrity, acceptable hygiene, status of hard and tissue supporting structures, and biological response, are but a few concerns that need to be monitored on a routine basis throughout treatment. When patients miss their appointments, sometimes for prolonged periods of time, things can go wrong and patients can suffer from self-contributed injuries. When doctors keep recalcitrant patients in unsupervised therapy, it sometimes rises to the level of supervised neglect for which the doctor may incur liability. Courts have addressed this issue, and as one court¹² noted

If a patient fails to come to the office or fails to return to the office for further treatment, he is not entitled to maintain an action against the physician, because of his own default and misfeasance.

At this point, we need to talk about the 600-pound gorilla sitting in the corner of the room; y’all know what I’m talking about; it’s the patient who for whatever reason is not keeping up with their financial obligations. Besides practicing a branch of healthcare, doctors are also running a small business and as such have financial obligations they must meet. They do this by charging for their professional services. Courts have always protected a practitioner’s right to earn a living. As noted in the following two legal decisions, “[...]a physician is entitled to protect his ability to generate an income and need not accept a prospective patient who cannot pay the fee charged all patients.”¹³ In addition, “[a]bandonment was not established after bookkeeper told patient she would no longer be seen because she had not paid her bill.”¹⁴ The only admonishment here is that you cannot sever the relationship if the patient is in “extremis.” This exists when the patient is at a precarious point in their treatment or when the patient presents with pain, swelling, bleeding or other unstable conditions. If this occurs, you must stabilize the patient first by getting them to a point in treatment where they can leave your practice unsupervised for a reasonable period of time during which they should be seeking substituted care.

In order to practice both effectively and efficiently, dentists require their patients to provide certain

information. We need specific personal and occupational information in order to facilitate billing and other administrative functions. We also need to obtain an adequate medical and dental history to support certain clinical needs and decisions. When patients intentionally or inadvertently withhold such information, they are in essence breaching one of their RODs owed under the umbrella of the doctor-patient relationship. As noted by the Axelrad¹⁵ court, "...a patient has a duty to respond accurately and truthfully to all questions posed to him."

The final ROD owed by patients to their doctors is the requirement to conform to accepted modes of behavior. If they do not, it is extremely possible that allowing patients to act in such an obstreperous manner could be claimed to constitute workplace harassment by one of the doctor's employees, and this in turn could subject the doctor to liability in that regard. As the Payton¹⁶ case revealed, "...[k]idney specialist and clinic had no legal obligation to continue providing dialysis treatment to an unruly and uncooperative patient..."

Now that we have reviewed the "why" one can legally terminate the doctor-patient relationship, the next step is to familiarize oneself with the "how" – the right way – if one is to mitigate against potential claims of patient abandonment. The Lee¹⁷ court defined patient abandonment as the unilateral severance of the doctor-patient relationship by the doctor without providing reasonable notice and at a time where the patient is still in need of continued medical attention of some sort. The claim of abandonment can also arise from the doctor not being available to provide follow-up care,¹⁸ "[a] dentist ...is under the duty not only to use the requisite care and skill in a particular operation, but also to give such follow-up care to the patient as is necessary...". It can also occur if there is a failure to provide emergency care or coverage,¹⁹

In demonstrating that a physician abandoned his patient, a plaintiff must show the physician became unavailable to treat the patient at a time when he knew the patient was at a critical stage of treatment; the physician failed to provide sufficient notice to enable the patient to secure another physician, or failed to arrange for substituted care for the patient in his absence.

It also arises when a doctor fails to provide a patient with substitute temporary coverage,²⁰ "[a] physician is under the duty to give a patient all necessary and continued attention as long as it is required ... while making suitable arrangements for attendance by another physician."

Finally, it also incorporates the concept of constructive abandonment that occurs when practitioners slow down treatment or refuse to offer the patient continued appointments because of an outstanding balance on the patient's account. As noted in the Watkins²¹ decision

The standard of care "very clearly" requires a dentist to continue to see an orthodontic patient regardless of an outstanding balance on his account. It requires a dentist to continue treating

a patient who is not making payments unless and until the dentist sends the patient a letter terminating the doctor-patient relationship and provides the patient with an opportunity to find another orthodontist.

The ideal format for dismissing a patient and terminating the doctor-patient relationship is by letter. Yes, it can be done verbally or using email. The key is to ensure that there is written documentation of the process. In that vein, the practitioner needs to provide the patient with Notice and Basis. Notice is the letter or email itself, either of which is sufficient, however proof of having provided notice to the patient falls on the shoulders of the doctor. This is most often accomplished using Certified Mail – Return Receipt Requested. Regular mail using a Certificate of Mailing offers the same support.

Basis is the legally accepted reason that you are choosing to terminate the doctor-patient relationship. There are 6 legally accepted reasons that practitioners can use to dismiss patients from their practices; so, the first paragraph of your dismissal letter will inform the patient as to why you are taking the action that you are. The next paragraph will inform the patient they still require continued care and that you are instructing them to do so in a timely manner. The third paragraph informs your patient that you will be available for a suitable period of time, for emergencies or referrals only, during which they should be seeking alternative care. Finally, you will make the patient's records available to them or to the substituted practitioner. As noted in the Osborne⁴ decision

The physician has a definite right to withdraw from the case provided he gives the patient reasonable notice so as to enable him to secure other medical attendance. Such a withdrawal does not constitute an abandonment.

There are many patient dismissal letters that exist. Various practice management individuals and companies, risk management educators, as well as numerous professional organizations have developed them. The following is one type of communiqué. Feel free to adopt or to tweak it as necessary to suit your needs. In the second paragraph, if the patient requests help in finding another orthodontist you can (1) give them the names of a few doctors in your area; (2) copy a page from any number of online sites; (3) give the patient the phone number of a local teaching hospital, clinic or school; or (4) provide the patient with the number of the local dental society for their referral base.

When I am out giving orthodontic risk management lectures around the country, one sentence I hear all the time from fellow practitioners is that "the orthodontics is the easy part; it's the practice management stuff that seems to drive everyone crazy." An adage that I have heard over and over again from practice management gurus is that 90% of a clinician's problems are caused by 10% of his patients. Knowing the right way to get out of a bad situation is the key to managing at least one of the administrative stressors we all occasionally face.

Figure 1

Sample Letter

Dear _____ :

Due to the fact that (choose from one or more of the six categories below) we must inform you that we are withdrawing from rendering further professional attendance to (your / your child's) orthodontic needs.

Since (her / his / your) dental condition requires further treatment, we urge that you seek continued orthodontic care and treatment with another practitioner without delay.

If you wish, we will be available to attend to any orthodontic needs you may have for the next (30, 45, 60) days on an emergency basis only or to help you in finding another doctor.

Should you authorize the release of your / your child's orthodontic records, we will be happy to forward them to you or the practitioner of your choice along with any other clinical information concerning the diagnosis and treatment rendered by us.

We regret having to take this action, but the situation as noted above has left us no other option.

Respectfully,

1. There has been a lack of cooperation regarding following instructions which has been very detrimental to (your / your child's) dental health thus potentially compromising our ability to achieve an adequate orthodontic result,
2. We are unable to arrive at a mutually agreeable clinical plan for addressing (you / your child's) clinical needs,
3. After repeated attempts, we are unable to coordinate the scheduling of appointments which in turn is jeopardizing (your / your child's) treatment,
4. You have not kept up with your financial obligations, under the terms that you agreed to, to pay for orthodontic services rendered,
5. You have not been honest and forthright in dealing with our office regarding certain clinical or administrative aspects of the professional services rendered,
6. There are significant interpersonal differences and problems between (you / your child) and members of our office staff which have created disharmony and/or disruption to our daily office routine and activities,

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Disclaimer: This article is provided for general educational and practice-management purposes only and does not constitute legal advice. Laws, regulations, and professional requirements governing the termination of the doctor-patient relationship may vary by jurisdiction and individual circumstances. Practitioners should consult applicable state and local requirements and seek qualified legal counsel when appropriate.

A Historic IAO Experience Is Coming to Sydney!

The IAO is taking its Annual Meeting to Sydney, Australia, and this is a milestone you won't want to miss!

The IAO is taking its Annual Meeting to Sydney, Australia, and this is a milestone you won't want to miss!

For only the second time in the association's history, the IAO's flagship continuing education event will be held internationally. This extraordinary meeting represents more than a change of scenery. It is the realization of a vision shared by IAO President Dr. Lee Willis: bring together world-class orthodontic education and one of the world's most spectacular destinations.

For Dr. Willis, there was no better choice than Sydney.

Making an international Annual Meeting a reality required tremendous planning, coordination, and attention to detail. As always, every lecturer was carefully selected to meet the IAO's high educational standards. But the goal was to create something even more special: a program that would bring together an exceptional collection of orthodontic educators

from around the world.

To help make that vision a reality, Dr. Willis reached out to two of Australia's premier orthodontic educators for general practitioners, Dr. Geoffrey Hall and Dr. Martin Poon of OrthoED. Drs. Hall and Poon share the IAO's passion for making advanced orthodontic knowledge accessible to dental practitioners. As keynote speakers, they helped establish the foundation for an extraordinary educational program and brought together an impressive network of clinicians and educators who share their commitment to education.

The result is a truly international lineup, featuring leading orthodontic voices from Australia, the United States, Spain, and the Philippines.

The 2027 Sydney Annual Meeting promises to deliver an educational experience unlike any other, with exceptional speakers, compelling topics, practical knowledge, and a global perspective on modern orthodontic care.

And that's just the beginning

A thrilling lineup of expertly led lectures was only one half of Dr. Lee Willis' vision for the 2027 IAO Annual Meeting. His goal was bigger: to combine an exceptional educational experience with a destination worthy of a place on every traveler's bucket list. That destination is Sydney, Australia.

Attendees will have the opportunity to experience one of the world's most spectacular cities while enjoying the high-caliber continuing education the IAO is known for. To make the experience truly extraordinary, the IAO searched for the perfect venue, and found it at the Sheraton Grand Hyde Park Sydney. Your home in the heart of Sydney.

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earliest European settlement. The adventure begins the moment you step outside the hotel.

More Than a Meeting — An Experience to Remember

The IAO Annual Meeting has always been about more than lectures. It is about people, relationships, shared experiences, and professional connections that last long after the meeting ends. The 2027 Annual Meeting will provide countless

opportunities for attendees to connect with colleagues, exchange ideas, relax, and celebrate together.

Signature IAO experiences include the President's Reception, General Assembly, Table Clinic and Case of the Year displays, and Saturday Night Celebration. Attendees will have opportunities to enjoy great food, drinks, conversation, and learning together outside the lecture halls.

And in Sydney, the social experience takes on an entirely new dimension.



Experience Sydney Together

The IAO has created special opportunities for spouses and guests to experience some of Sydney's most iconic attractions.

Sydney Harbor Night Cruise

Spouse/Guest registration includes the opportunity to join an unforgettable evening cruise aboard the Majestic II, a luxury catamaran. Doctors may also purchase tickets to join their guests. Enjoy a three-course meal, complimentary beer and wine, and spectacular views of Sydney Harbor as the city lights begin to sparkle around you. With the Sydney Opera House and iconic skyline as your backdrop, this promises to be an evening you will remember for years to come.

Sydney Opera House Tour

Spouse/Guest registration also includes a guided tour of the world-famous Sydney Opera House, with doctors again having the opportunity to purchase tickets. Step inside one of the world's most recognizable architectural landmarks and discover the history, stories, and remarkable design behind this legendary cultural icon.

These aren't simply activities on an agenda. They are opportunities to experience Sydney together and create memories that will last a lifetime.

World-Class CE. Extraordinary Destination. Unforgettable Memories.

The IAO understands how important it is for dental professionals to remain at the forefront of a rapidly changing profession. That is why the association takes tremendous pride in developing an educational program featuring exceptional speakers, relevant topics, and meaningful learning experiences. The IAO also recognizes how much dentists give to their profession. There are long hours treating patients, coordinating staff efforts, building a business, and maintaining a dental license. Attendees deserve an Annual Meeting that gives something back.

That is why Dr. Willis was so passionate

about making Sydney different. The 2027 IAO Annual Meeting brings together three extraordinary elements: exceptional continuing education, meaningful professional connections, and a once-in-a-lifetime destination

For many attendees, this may be a once-in-a-lifetime opportunity to experience Sydney in this way. Come for the education, and stay for the experience. Explore the city, experience the harbor, create memories with colleagues and friends, and leave Sydney with more than CE credits. Leave with new ideas, new relationships, and memories that will last a lifetime.

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Dr Geoffrey Hall

AUTHOR

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Specialist Orthodontist
Founder and Director, The OrthoED Institute

I have spent 36 years in practice watching orthodontics reinvent itself, and I am convinced the next decade will bring sharper change than anything we have seen so far.

Looking back, three threads explain how we arrived here, and they will keep shaping how we diagnose, plan and deliver care: the precision engineering of our appliances, the digital revolution that now sits under almost everything we do, and the recurring cycle of trend-driven therapies that test our judgement. Here is where I believe each is heading, and, more importantly, what will not change no matter how good the technology becomes.

Precision Engineering: from Artistry to Reproducible Science

The refinement of the straight-wire appliance has been the quiet backbone of modern orthodontics. When I started, straight-wire treatment demanded a great deal of manual artistry: bands crimped just so, wires contoured by hand, and a heavy reliance on the clinician's tactile sense to predict tooth movement. Over time the wires themselves were preformed to tighter, more predictable shapes and paired with more precise brackets and ligatures. The result was not simply a faster path to alignment; it was a more reproducible science.

The automation of wire bending is the leading edge of this same trend. Technologies such as SureSmile and the bending robot move us from craft to controlled automation, sculpting wires with a precision that reduces manual variability and shortens treatment. They also make genuinely personalised wire sequences possible, responding to each patient's tooth-movement dynamics. As the technology matures I expect real-time monitoring of wire behaviour, tighter integration with the digital plan, and a larger toolkit for complex movements. The point is not to replace clinical judgement but to augment it: to deliver consistent wire performance, to take the guesswork out of the routine, and to free us to do what we do best, which is to solve problems in the context of each patient's history.

Looking further ahead, I expect hardware that delivers

gentler and more efficient movement, with better control of root position and occlusion. We will see materials that are kinder to the periodontium, bracket interfaces intelligent enough to adapt to individual tooth biology, and finishes that produce not just straight teeth but optimal bite function with a lower risk of relapse.

The digital revolution and aligner therapy

We have entered the era of digital orthodontics, and aligner therapy has become its cornerstone. Digital scanning, computer-guided planning and precisely manufactured appliances have moved much of the predictability and convenience that once belonged to fixed braces. Aligner therapy in particular embodies a philosophy of staged, patient-friendly correction that can be planned end to end in a virtual space before a single tooth moves in the mouth.

The implications are significant: more accurate simulation of outcomes, customisation down to the smallest aesthetic and functional detail, and a tighter feedback loop between the predicted result and real progress. I expect far closer integration of imaging, artificial intelligence and patient-engagement tools, so that patients understand their trajectory and stay committed to the plan. In practice that means shorter chair time for routine adjustments, earlier detection of the cases that are drifting off track, and treatment that respects each patient's biology and lifestyle.

The cycle of trend-driven therapy

We also need to be honest about the fads that move through our profession, from myofunctional therapy to a long line of trend-driven approaches. Some of these have gained traction more for their marketing appeal than for any robust long-term evidence. They arrive with great confidence, attract a following, and then recede when the results do not hold up. This cycle is not going away, and it is precisely why the next point matters more than any device or platform.

What never changes: diagnosis and biomechanics

There is no doubt that orthodontics will keep getting more efficient. But efficiency is not the same as competence, and we can never neglect patient management, communication and, above all, diagnosis. More to the point, we have to understand biomechanics: the forces and the reactive forces, and the distinction between consistent and inconsistent force systems. No single appliance, and no single piece of software, supplies all of the answers. The success of a case still depends on sound diagnosis and treatment planning grounded in those force concepts.

Once you have mastered diagnosis and treatment planning on that basis, either a straight-wire appliance or an aligner system can produce excellent results. The system is the instrument; the diagnosis is the music.

My prediction: the hybrid decade I believe the next ten years belong to a hybrid model. We will use fixed-appliance therapy for roughly four to six months to achieve the most difficult movements, then move to aligners for fine tuning. The whole sequence will be followed through remote monitoring systems such as Dental Monitoring, or, as I prefer, Grin. This is not a compromise between two camps. It is the logical combination of each system's strengths: the control of fixed appliances where the case is hardest, and the precision and patient comfort of aligners where it counts for finishing.

For the general dentist, the message is simple. Invest in your diagnosis and your grasp of force systems first. The hardware will keep improving around you, but that foundation is what will let you choose the right tool, in the right sequence, for the patient in front of you.

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Article: *Evaluation of Tooth Size Discrepancy and Bolton Tooth Size Analysis in Different Angle's Malocclusion Groups: A Case Study*

According to the study, which malocclusion group had a significantly higher anterior Bolton ratio than Class II patients?

- A. Class I
- B. Class III
- C. Both Class I and Class III
- D. Neither Class I nor Class III

Article: *Space Closure vs. Space Opening: Solving Diastema in Hypodontia: A CASE REPORT*

True or False: In this case, the treatment plan involved opening spaces for congenitally missing teeth rather than retracting the existing dentition.

Article: *Vertical Control of the Maxillary Dentition for Non-Surgical Correction of a Severe Gummy Smile: A Case Study*

Which method was used in this case to provide skeletal anchorage for intrusion of the maxillary dentition?

- A. Mini-implants
- B. Headgear
- C. Functional appliances
- D. Intermaxillary fixation

Article: *External Root Resorption Associated with Displaced Permanent Maxillary Canines: A Cone-Beam Computed Tomographic Analysis*

Which type of displaced maxillary canine was significantly associated with an increased incidence of external root resorption (ERR) of adjacent teeth?

- A. Palatally displaced canine
- B. Buccally displaced canine
- C. Canine displaced in the line of the arch
- D. All positions equally

Article: *Bonding Orthodontic Metal Brackets to Composite Restorations: An Evaluation of the Bonding Effectiveness of Two Adhesive Systems*

Which factor significantly increased shear bond strength in this study?

- A. Diamond bur surface roughening
- B. Increasing the thermocycling temperature.
- C. Increasing bracket bonding pressure
- D. Use of Single Bond Universal Adhesive

Article: *Infrazygomatic Crest Mini-Implants (IZC) for Skeletal Class II Correction in Monozygotic Twins*

True or False: In these monozygotic twins, the line of action of the force from the IZC mini-implants was designed to pass through the maxillary center of resistance to minimize unwanted rotation of the occlusal plane.

Article: *Recent Advances in Biocompatible Shape Memory Polymers for Craniofacial and Orthodontic Applications: From Material Design to 3D/4D Printing*

Which statement best describes the current clinical status of shape memory polymers (SMPs) in orthodontics according to this review?

- A. They are established as the standard material for clear aligners.
- B. They have largely replaced conventional orthodontic polymers.
- C. They are an emerging research platform, with much of the evidence still preclinical.
- D. They are approved primarily for routine craniofacial implants.

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