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Turkish Orthodontic Society

# TURKISH JOURNAL of ORTHODONTICS

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Esthetic versus conventional Twin Block Appliances

Cephalogram vs CBCT for Quantitative Comparison of Alveolar Thickness

Low-Viscosity Resin Infiltration Efficacy

Nahoum Index in Brachyfacial Patients

Dental age in Individuals with UCLP

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## REVIEW

Risk Management During Impacted Maxillary Canine Treatment

Laser in Orthodontics

## INTERVIEW

Interview with Dr.Ravindra Nanda on Current Concepts in Orthodontics

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Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

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| REVIEW ARTICLE | 5000 | 250 | 50 | 6 | 10 or total of 20 images |
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| LETTER TO THE EDITOR | 500 | No abstract | 5 | No tables | No media |

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**Thesis:** Yılmaz B. Ankara Üniversitesindeki Öğrencilerin Beslenme Durumları, Fiziksel Aktiviteleri ve Beden Kitle İndeksleri Kan Lipidleri Arasındaki Ilişkiler. H.Ü. Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2007.

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Original Article

# Is There Any Difference Between Gonial Angle Values Measured on Digital Lateral Cephalograms and Orthopantomograms?

Demet Kaya

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Cite this article as: Kaya D. Is There Any Difference Between Gonial Angle Values Measured on Digital Lateral Cephalograms and Orthopantomograms? Turk J Orthod 2020; 33(2): 72-6.



## ABSTRACT

**Objective:** To determine whether there is a difference between the gonial angle (GoAng) values measured on digital lateral cephalograms (Lat Cephs) and orthopantomograms (OPGs) using a software.

**Methods:** This study was conducted by examining the digital Lat Cephs and OPGs of 51 patients (9 males, 42 females) who received orthodontic treatment. The mean age of the patients was 19.51±4.92 years. All digital radiographs were acquired with the same machine. The GoAng measurements were performed digitally using TotalCeph software. In order to evaluate the difference between the GoAngs measured on the digital Lat Cephs and OPGs, a paired t-test was used. To compare the two techniques (digital Lat Ceph and OPG) in terms of GoAng measurement, Bland-Altman analysis was used. The differences between the right and left GoAngs measured on the digital OPGs were evaluated using a paired t-test. The intraobserver reliability was assessed with the intraclass correlation coefficient (ICC) for repeated measurements.

**Results:** The intraobserver reliability was 0.99 for repeated measurements. There were no statistically significant differences between the GoAngs measured on digital Lat Cephs and OPGs (p=0.1). Bland-Altman analysis showed high levels of agreement between digital Lat Cephs and OPGs with a bias value of −0.4° for GoAng measurement. Moreover, the differences between the right and left GoAngs measured on the digital OPGs were not statistically significant (p=0.73).

**Conclusion:** The results of this study demonstrated that the digital OPGs were as reliable as the digital Lat Cephs for measuring Go angles using a software.

**Keywords:** Digital, Gonial angle (GoAng), lateral cephalogram (Lat Ceph), orthopantomogram (OPG), software

Main points:

- There were no statistically significant differences between the GoAngs measured on digital Lat Cephs and OPGs.
- The levels of agreement between the digital Lat Ceph and OPG were high for GoAng measurement.
- The differences between the right and left GoAngs measured on digital OPGs were not statistically significant.

## INTRODUCTION

The gonial angle (GoAng) is an important measurement for diagnosis and treatment planning in orthodontics. It is used for evaluating mandibular rotation, diagnosing growth patterns, determining tooth extraction patterns in Class II patients, planning orthognathic surgery in Class III patients, and predicting age in forensic medicine (1-5).

Usually, GoAng is measured on lateral cephalograms (Lat Cephs). However, the accuracy of GoAng measurements may be affected by the superimposition of the patient's right and left sides (6). To measure the GoAng accurately, orthopantomograms (OPGs) are used instead as the right and left GoAngs are not superimposed and can be measured individually (7). Conflicting results have been published regarding whether there is a dif-

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ference between these radiographs (7-11). Some authors have reported that OPGs are more accurate than Lat Cephs, whereas others have reported no statistically significant difference (7-9). Araki et al. (10) studied dry skulls and found that the GoAngs measured on OPGs were slightly smaller than those measured on Lat Cephs. In these studies, different mandibular or ramal planes were used and measurements were made manually on printed images (7-11).

The different techniques used to obtain measurements make it difficult to compare the results of different studies. Therefore, the purpose of this study was to determine whether there was a difference between GoAng measurements, constructed by using easily identifiable mandibular and ramal planes, on digital Lat Cephs and OPGs using a software.

## METHODS

The present study was approved by the Ethics Committee of Hacettepe University Medical School with the approval number GO 18/65-24. Patients were informed about the study in detail and written informed consent forms were obtained from the patients who agreed to take part in the study.

The study was conducted using the digital Lat Cephs and OPGs of 51 patients (9 males and 42 females) who underwent orthodontic treatment at the Oral and Dental Health Care Clinic, Gün Hospital, Hacettepe University, between August 2016 and December 2017. The mean age of the patients was 19.51±4.92 years. Digital Lat Cephs and OPGs were acquired using Castellini X Radius Trio 2D (version 6.2; iRYS Imaging, Italy) by the same technician using the same device for all the patients in the natural head position. All radiographs were viewed and evaluated, and only high quality radiographs were included in the study. The exclusion criteria for this study were a history of trauma, surgery, syndromes, and asymmetry related to the face or jaw.

The GoAng measurements were obtained digitally using the 1.2.0 version of TotalCeph software (Torc Software Solutions, Istanbul, Turkey). The software allows free measurement. Digital images of each Lat Ceph and OPG were imported directly into the TotalCeph software for on-screen digitalization. On both radiographs, lines tangential to the mandibular lower border (mandibular plane) and those tangential to the posterior border of the ramus and condyle (ramal plane) were drawn. Anatomic landmarks required for constructing the tangential lines were determined by using a ruler and then digitized. The software automatically measured the GoAng at the point of intersection of these two lines (Figures 1 and 2). On the OPGs, the GoAng was measured for both left and right sides. The measurements were conducted twice over an interval of one month.

The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used for data analysis. The normality of the data was tested with the Kolmogorov-Smirnov test. In order to evaluate the difference between the GoAngs measured on the digital Lat Cephs and OPGs, a paired t-test was used. To compare the two techniques (digital Lat Ceph and OPG) in terms of GoAng measurement, Bland-Altman analysis was used (12). In addition, the difference between the right and left GoAngs measured on the digital OPGs was evaluated using a paired t-test. A p value less than 0.05 was considered to be statistically significant. The intraobserver reliability was assessed with the intraclass correlation coefficient (ICC; type 3, 1) for repeated measurements.

## RESULTS

The intraobserver reliability was 0.99 for repeated measurements, which indicated excellent reliability.

The mean values of the GoAngs were 123.71°±6.88° and 123.30°±6.47° for digital Lat Cephs and OPGs, respectively (Table 1).

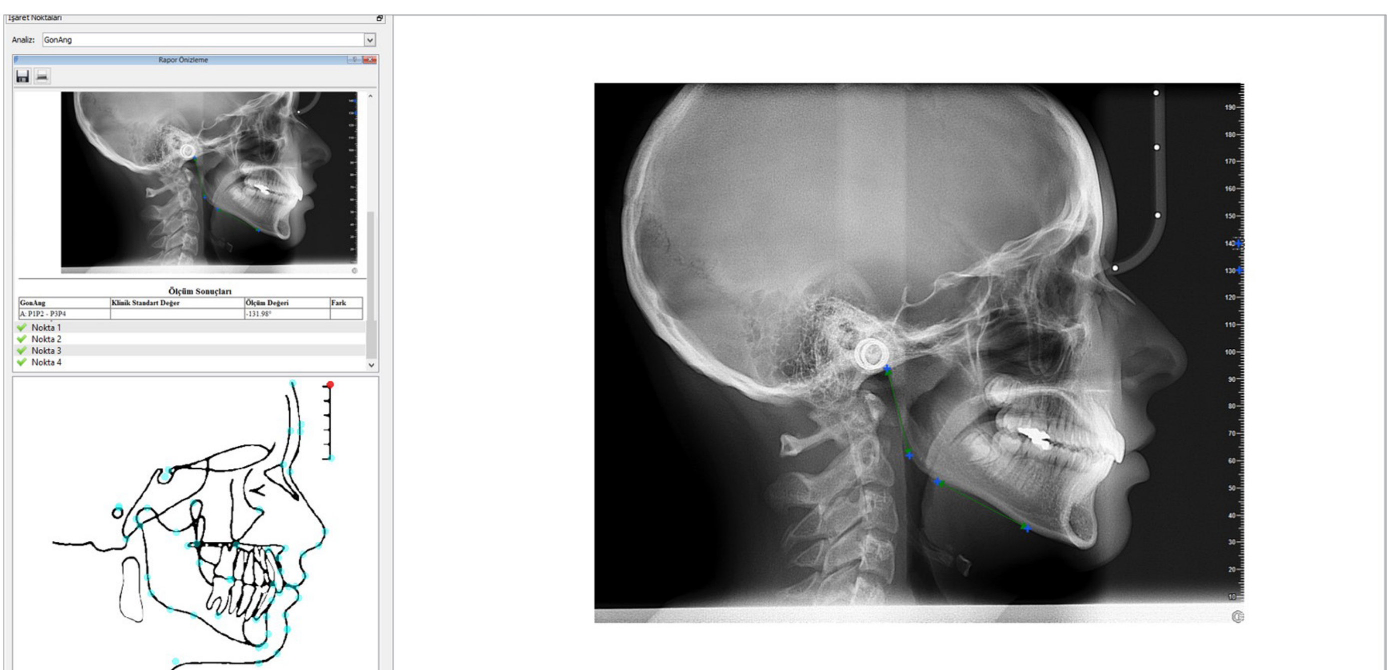

**Figure 1.** Gonial angle measurement on a digital lateral cephalogram.

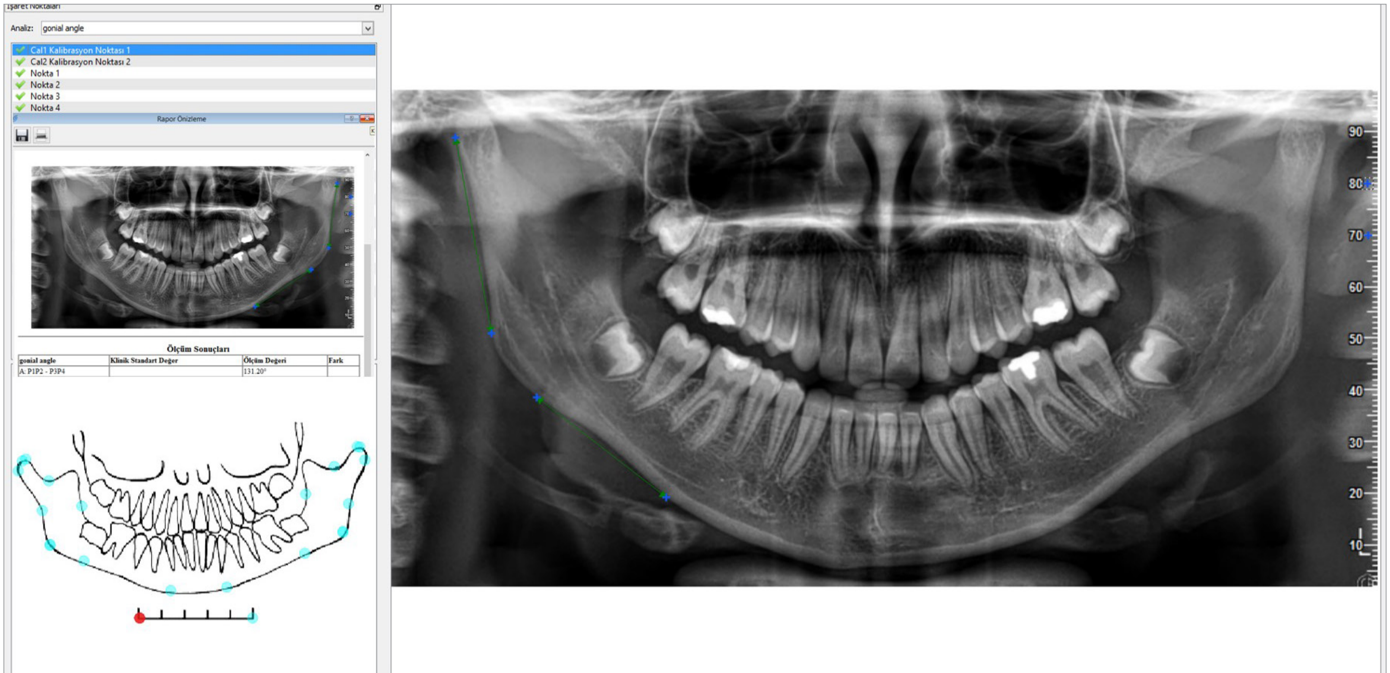



**Figure 2.** Gonial angle measurement on a digital orthopantomogram.

**Table 1.** The minimum, maximum, and mean values of gonial angles (GoAngs) measured on digital lateral cephalograms (Lat Cephs) and orthopantomograms (OPGs).

| GoAng | Min (degree) | Max (degree) | Mean±SD (degree) | p value |
|---|---|---|---|---|
| Digital Lat Ceph | 107.4 | 140.6 | 123.71±6.88 | 0.10 |
| Digital OPG | 107.4 | 136.9 | 123.32±6.47 | |
| Digital OPG (Right) | 107.1 | 137.7 | 123.25±7.04 | 0.73 |
| Digital OPG (Left) | 107.7 | 138.7 | 123.44±6.54 | |

Min: minimum value; Max: maximum value; SD: standard deviation; significant at p<0.05

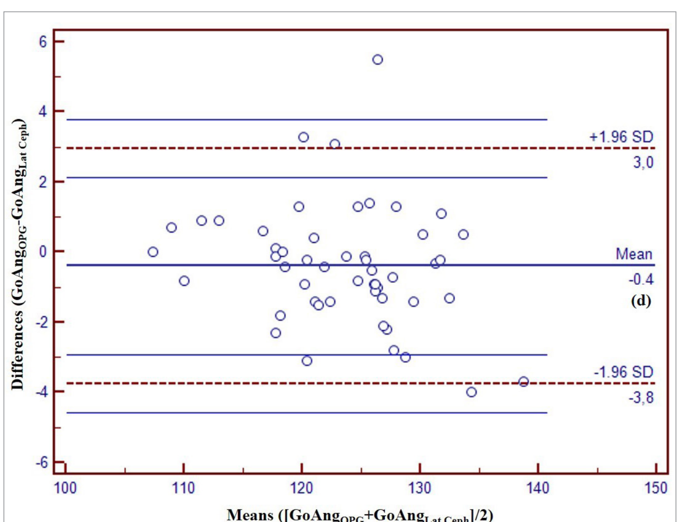


**Figure 3.** This plot represents the differences between the gonial angles measured using lateral cephalogram digital orthopantomogram (OPG) versus their mean values. In the plot the thick horizontal plane represents the mean values of all differences, *d,* a quantity known as the *bias.* The dashed lines represent the 95% limits of agreement and they enclose 95% of the experimental points. The thin solid lines next to the limits of agreement depict 95% confidence intervals. Differences and means were represented as one point for each patient.

There was no statistically significant difference between the measured GoAngs (p=0.1) (Table 1). According to Bland-Altman analysis, the levels of agreement between the digital Lat Ceph and OPG were high for GoAng measurement, with a bias value (95% levels of agreement) of –0.4° (figure 3). The mean values of the right and left GoAngs on the digital OPGs were 123.25°±7.04° and 123.44°±6.54°, respectively. The difference between these measured angles was also not statistically significant (p=0.73) (Table 1).

## DISCUSSION

The purpose of this study was to determine whether there was a difference between the Gonial angles, constructed using easily identifiable mandibular and ramal planes, measured on digital Lat Ceph versus digital OPG using the 1.2.0 version of TotalCeph software. Only radiographs obtained between August 2016 and December 2017 were included in this study because radiographs recorded in our clinic before August 2016 were not digital.

The GoAng is measured at the point of intersection of the mandibular and ramal planes. It has been reported that the GoAng value varies depending on the type of mandibular or ramal plane used (7, 13). The mandibular plane could be assessed either by using a line tangential to the mandibular lower border or by drawing a line between the gonion and gnathion or the gonion and menton. The ramal plane could also be assessed at different points, such as the articulare and gonion or by using a line tangential to the posterior border of the ramus and condyle. The points of the gnathion, menton, and articulare can be easily identified on Lat Ceph but not on OPG (7). Erroneous identification of these anatomic points on OPGs may result in inaccurate measurements. The lines tangential to the mandibular lower border and posterior border of the ramus and condyle can be easily identified on both radiographs and are, therefore, considered to be acceptable for comparison of the GoAngs measured on Lat Ceph and OPG (7). Thilagarani et al. (14) concluded that GoAngs constructed using Tweed's mandibular plane (a line tangential to the mandibular lower border) on Lat Cephs were highly correlated with those obtained on OPGs. Therefore, in this study, to obtain accurate measurements, GoAngs were measured at the point of intersection of the lines tangential to the mandibular lower border and those tangential to the posterior border of the ramus and condyle on both types of radiographs. The measurements on both radiographs were performed digitally using the TotalCeph software. The use of the software in radiograph analysis is simpler and less time consuming when compared with manual measurements. To the best of the author's knowledge, to date, there has been no study assessing the differences between the GoAngs measured on digital Lat Ceph and OPG using a software. All measurements were conducted twice to test the reliability of the observer. The intraobserver reliability was excellent, indicating that the GoAng can be measured precisely.

In practice, the GoAng is generally measured on Lat Cephs. The left and right gonial regions are superimposed on these radiographs, which can result in inaccurate measurements (6). The GoAng measurement on a Lat Ceph is the arithmetic mean of the superimposed right and left GoAngs. Any distortion of the right or left gonial regions affects the value of the measured GoAng (15). Concerns regarding the superimposition of the right and left gonial regions on Lat Cephs, which are made worse by any distortion of these regions prompted researchers to measure the GoAng on OPGs because the right and left gonial regions are not superimposed; therefore, GoAngs can be measured separately regardless of the possible effect of image distortion on the measurements (7-11, 14, 16).

In this study, the mean values of the right and left GoAngs measured on digital OPGs were slightly smaller than those reported by Shahabi et al. (8), who used the same mandibular and ramal planes for GoAng measurements as were used in this study. There were no statistically significant differences between the right and left GoAngs on the digital OPGs; this was in accordance with the results of prior studies (8, 9). The values from the digital OPGs were slightly smaller than those obtained from the digital Lat Cephs. However, the differences were not statistically significant, a finding that was also consistent with the results of Shahabi et al. and Radhakrishnan et al. (8, 9). Araki et al. (10) had results similar to those in this study, although they used different mandibular and ramal planes. Moreover, it has been demonstrated in previous studies that the correlation between measured GoAngs on Lat Ceph and OPG is high (17). In contrast, Fisher-Brandies et al. (11) reported that the GoAng measured on OPGs was 2.2°-3.6° less than the angle measured on Lat Cephs, which was statistically significant; they preferred Lat Ceph for GoAng measurement. Mattila et al. (7) stated that the GoAngs measured on OPGs were more accurate than those measured on Lat Cephs and OPGs of dry skulls. The differences between the results of these studies may be due to the sample sizes, patient ages, or the different methods used for GoAng measurement. This study demonstrated that the two techniques (digital OPG and Lat Ceph) gave similar results in terms of GoAng measurement. The measurement precision is important for comparing the two techniques. In this study, the measurement precision was 0.5°. The bias value of 0.4° was clinically irrelevant from the point of view of clinical practice. Nonetheless, the reliability of this result depends on the clinic discretion of the orthodontist.

The gender differences between the measured GoAngs from each type of radiograph were not evaluated, as the number of male patients was low in this study. Furthermore, previous studies have failed to demonstrate any statistically significant gender differences in the GoAngs obtained from either type of radiograph, so this was not evaluated in this study (8, 18, 19).



The results of this study imply that the digital OPGs are as reliable as the digital Lat Cephs for GoAng measurements using TotalCeph software. The decision regarding the type of radiograph to be used for GoAng measurement depends on the orthodontist's preference. Right and left GoAngs can be measured individually on digital OPGs, as the left and right sides are not superimposed, which is a significant advantage over Lat Cephs. This is especially important when planning orthognathic surgery in patients with asymmetries. However, further studies with larger sample sizes are required to improve the precision of the data.

## CONCLUSION

The digital OPGs were as reliable as the digital Lat Cephs for measuring GoAngs using a software.

**Ethics Committee Approval:** This study was approved by the Ethics Committee of Hacettepe University Medical School with the approval number GO 18/65-24.

**Informed Consent:** Written informed consent was obtained from the patients who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Conception - D.K.; Design - D.K.; Supervision - D.K.; Data Collection and/or Processing - D.K.; Analysus and/or Interpretation - D.K.; Writing Manuscript - D.K.; Critical Review - D.K.; Literature Search - D.K.

**Conflict of Interest:** The author has no conflict of interest to declare.

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## REFERENCES


1. Ødeg J. Mandibular rotation studies with the aid of metal implants. Am J Orthod 1970; 58: 448-54. [Crossref]
2. Athanasios EA. Orthodontic cephalometry. London: Mosby-Wolfe; 1995. pp. 81.
3. Nanda SK. Growth patterns in subjects with long and short faces. Am J Orthod Dentofacial Orthop 1990; 98: 247-58. [Crossref]
4. Tahmina K, Tanaka E, Tanne K. Craniofacial morphology in orthodontically treated patients of class III malocclusion with stable and unstable treatment outcomes. Am J Orthod Dentofacial Orthop 2000; 117: 681-90. [Crossref]
5. Upadhyay RB, Upadhyay J, Agrawal P, Rao NN. Analysis of gonial angle in relation to age, gender, and dentition status by radiological and anthropometric methods. J Forensic Dent Sci 2012; 4: 29-33. [Crossref]
6. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. Am J Orthod Dentofacial Orthop 1986; 90: 45-51. [Crossref]
7. Mattila K, Altonen M, Haavikko K. Determination of the gonial angle from the orthopantomogram. Angle Orthod 1977; 47: 107-10.
8. Shahabi M, Ramazanzadeh BA, Mokhber N. Comparison between the external gonial angle in panoramic radiographs and lateral cephalograms of adult patients with Class I malocclusion. J Oral Sci 2009; 51: 425-9. [Crossref]
9. Radhakrishnan PD, Varma NKS, Ajith VV. Dilemma of gonial angle measurement: panoramic radiograph or lateral cephalogram. Img Sci Dent 2017; 47: 93-7. [Crossref]
10. Araki M, Kiyosaki T, Sato M, Kohinata K, Matsumoto K, Honda K. Comparative analysis of gonial angle on lateral cephalometric radiographs and panoramic radiographs. J Oral Sci 2015; 57: 373-8. [Crossref]
11. Fischer-Brandies H, Fischer-Brandies E, Dielert E. The mandibular angle in the orthopantomogram. Radiologe 1984; 24: 547-9. [Crossref]
12. Bland MJ, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet 1986; 327(8476): 307-10. [Crossref]
13. Dahan J, Jesdinsky HJ. Evaluation of the orthopantomogram for cephalometric studies in orthodontics. Stoma (Heidelb) 1968; 21: 200-6.
14. Thilagarani, Nadkerny PV, Kumar DA, Nadkerny VD. Assessing reliability of mandibular planes in determining gonial angle on lateral cephalogram and panoramic radiograph. J Orthod Res 2015; 3: 45-8. [Crossref]
15. Slagsvold O, Pedersen K. Gonial angle distortion in lateral head films: a methodologic study. Am J Orthod 1977; 71: 554-64. [Crossref]
16. Nohadani N, Ruf S. Assessment of vertical facial and dentoalveolar changes using panoramic radiography. Eur J Orthod 2008; 30: 262-8. [Crossref]
17. Bhullar MK. Uppal AS, Kochhar GK, Chacra S, Kochhar AS. Comparison of gonial angle determination from cephalograms and orthopantomogram. Indian J Dent 2014; 5: 123-6. [Crossref]
18. Altonen M, Haavikko K, Mattila K. Developmental position of lower third molar in relation to gonial angle and lower second molar. Angle Orthod 1977; 47: 249-55.
19. Dutra V, Yang J, Devlin H, Susin C. Mandibular bone remodelling in adults: evaluation of panoramic radiographs. Dentomaxillofac Radiol 2004; 33: 323-8. [Crossref]

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Original Article

# Comparison of Dentoskeletal Changes, Esthetic, and Functional Efficacy of Conventional and Novel Esthetic Twin Block Appliances among Class II Growing Patients: A Pilot Study

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## ABSTRACT

**Objective:** A twin block appliance used for correction of skeletal Class II malocclusion suffers from undesirable dental effects and bulkiness. To overcome these limitations and the need for more esthetic appearance of this appliance, an esthetic twin block was designed and used in patients. This study aimed to compare dentoskeletal changes and esthetic and functional efficacy in patients treated with conventional and newly designed esthetic twin block (CTB and ETB) appliances using cephalometric measurements and a questionnaire.

**Methods:** A pilot study with a 2-arm parallel-randomized double-blind clinical trial was conducted on 24 patients (20 males, 4 females) in the age group of 11-13 years. Subjects were treated with CTB (group 1 [G1]: n=12; mean age=11.67±0.49 years) and ETB (group 2 [G2]: n=12; mean age=11.75±0.62 years) appliances. A modified Pancherz analysis was performed to evaluate skeletal and dental changes. The esthetic and functional efficacy was evaluated by a questionnaire using Likert scale. Wilcoxon and Mann-Whitney U tests were employed for intra and intergroup comparisons respectively ($p<0.05$).

**Results:** In G1, a significant increase in lower incisor inclination was observed ($p<0.05$) whereas it was insignificant in G2. The changes were predominantly skeletal in G2 whereas they were both skeletal and dental in G1. ETB was found to be esthetically and functionally acceptable in all the patients while CTB patients were esthetically conscious, lacked confidence and had discomfort and difficulty in eating, chewing and speaking.

**Conclusion:** ETB had greater skeletal effects with a reduced tendency of lower incisor proclination, was esthetically acceptable, and functionally more comfortable than the CTB.

**Keywords:** Class II malocclusion, modified Pancherz analysis, twin block

Main points:

- Esthetic twin Block (ETB) has been found to be better in terms of esthetic and functional efficacy compared to the conventional twin block (CTB).
- ETB has a better control over lower incisor inclination compared to CTB.
- ETB should be preferred over CTB for mandibular advancement in growing Class II patients.

## INTRODUCTION

Patients with skeletal Class II malocclusion involving retruded mandible demand orthodontic care mostly due to their desire for facial esthetic improvement. Twin block (TB) is one of the most popular functional appliances to treat this condition in the growing phase over the last two decades and yields satisfactory results (1). Since the use of this appliance allows regular functional activities like mastication, it can be worn continuously resulting in faster treatment results compared to those with other functional appliances (2). Despite excellent treatment results with TB, its acceptance and compliance may be hampered by its bulky nature (3). Furthermore, it has an inherent limitation of causing the proclination of lower incisors, which reduces the potential to attain complete skeletal change (4). The position and inclination of the lower incisors in alveolar bone determines the stability

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of anterior occlusal contacts and avert gingival recession (5).Various modifications were proposed to circumvent lower incisors proclination, such as southened clasp, acrylic labial bow, ball clasps, and acrylic capping but had no significant effect (6-10). A recent modification suggested the use of a mini-implant to control lower incisor proclination (11). However, its use is limited by the invasive nature of the miniscrew placement.

The success of any appliance depends upon the comfort and esthetic acceptability, which ensures good patient compliance. Moreover, the hallmarks of treatment acceptance have changed contemporarily as the patients emphasize more on esthetics and comfort rather than only on mechanical or biological superiority (12, 13). Hence, in order to enhance esthetic appearance, alleviate bulkiness, and overcome the disadvantages of a conventional TB (CTB), a novel esthetic TB (ETB) was fabricated from a biocryl sheet (Duran® SCHEU Dental Technology, Germany) using a pressure molding device and cold cure acrylic bite blocks. This study was envisaged to compare the dentoskeletal changes and esthetic and functional efficacy of ETB with CTB using cephalometric measurements and a questionnaire.



## METHODS

### Study Design

The present study was conducted as a pilot initiative designed in a single clinical establishment as a 2-arm parallel, non-pharmacological, randomized double-blind clinical trial.

### Study Subjects and Inclusion Criteria

This study was conducted among individuals in the age group 11-13 years who reported to the Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, New Delhi, India, from July to December 2017 (six months). The subjects, who were recruited, had Angle's Class II division 1 malocclusion with a retrognathic mandible, a positive visual treatment objective (VTO), average to horizontal growth pattern along with cervical vertebrae maturation index (CVMI) in transition stage. A written informed consent was obtained from the parents of the subjects. The study was approved by the Institutional Research Ethical Committee (reference no. MAIDS 2015).

### Sample Size Calculation

The sample size was calculated using software G* Power (Universität Düsseldorf, Germany). In order to have a power of study of 0.95 with an alpha error of 0.05, a minimum of 22 subjects was required (11 in each group) to detect a significant difference of 1.5mm in the lower incisor protrusion (14). Considering a dropout rate of 10% during the study period, 24 subjects were recruited.

### Randomization and Allocation

Patients were equally divided into CTB (group 1, G1; 10 males, 2 females with a mean age of 11.67 ± 0.49 years) and ETB (group 2, G2; 10 males, 2 females with a mean age of 11.75±0.62 years) groups. A simple randomization method was performed using identical, sequentially numbered opaque sealed envelopes to ensure an allocation ratio of 1:1.

### Interventions

### CTB Appliance

CTB comprised of maxillary and mandibular removable appliances having the labial bow, delta clasps, and ball end clasps with incisal capping and expansion screw.

### ETB Appliance

The expansion screw (Leone® Italy) was positioned in the midline of maxillary cast with the help of cold cure acrylic (Figure 1a). Thereafter, 1-mm biocryl sheet was adapted separately on maxillary and mandibular casts with help of pressure molding Biostar machine

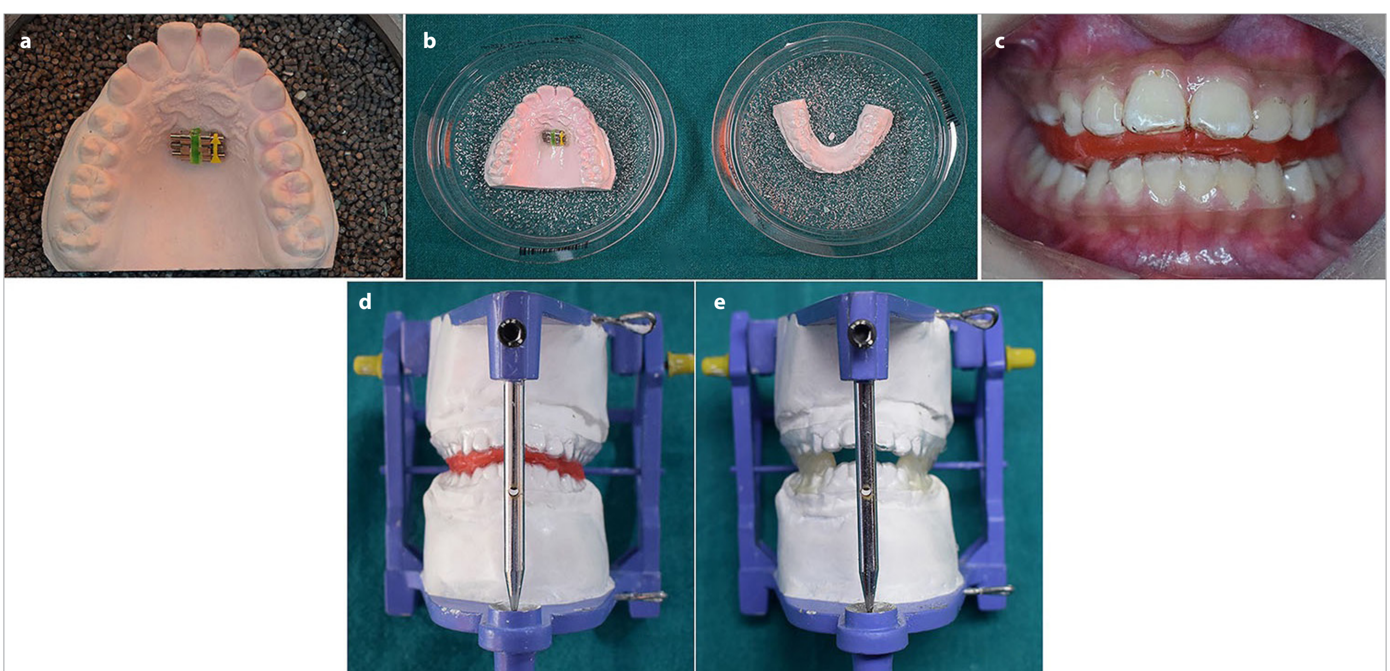


**Figure 1. a-e.** Steps in fabrication of ETB

Figure 2. Intraoral photographs with ETB



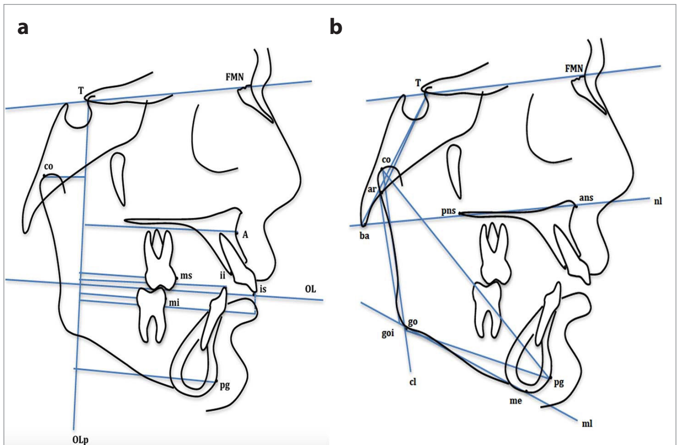


**Figure 3. a, b.** (a) Modified Pancherz analysis (Linear Dimensions). (b) Modified Pancherz analysis (Angular Dimensions). A, point A; ans, anterior nasal spine; ar, articulare; ba, basion; cl, condylar line; co, condylion; FMN, frontomaxillary nasal suture; go, goi, gonion; ii, incision inferius; is, incision superius; me, menton; mi, molar inferius; ml, mandibular line; ms, molar superius; nl, nasal line; OL, occlusal line; OLp, occlusal line perpendicular; pg, pogonion; pns, posterior nasal spine; T, tuberculum sella

(SCHEU Dental Technology, Germany). This ensured that the expansion screw got incorporated in the maxillary biocryl sheet (Figure 1b). The bite was registered with maxillary and mandibular adapted biocryl sheets in the mouth in a single-step mandibular advancement (Figure 1c). Working models having registered bite along with upper and lower adapted sheets were mounted on the articulator (Figure 1d). Acrylic bite blocks with the inclined plane were fabricated on biocryl sheets similar to CTB (Figure 1e) and the maxillary appliance was split midpalatally (Figure 2).

All the subjects in G1 & G2 were instructed to wear the appliance 24 hours per day including while eating. Regular wear of the appliance by the patient was subjectively assessed by the achievement of the pterygoid response wherein it became painful for the patient to retract the mandible due to the formation of a tension zone. The trimming was initiated in both groups after achieving a pterygoid response. However, in ETB, the biocryl sheet was relieved from the lower appliance in the first molar region bilaterally before proceeding with bite block trimming. The duration of myofunctional therapy in both groups was 9-12 months.

**Assessment of Treatment Changes**

1. Cephalometric evaluation

Lateral cephalograms of all patients were taken in a natural head position on the same cephalostat with teeth in centric occlusion at two stages - pretreatment (T0) and post myofunctional therapy (T1) (15). The cephalograms were traced and evaluated using modified Pancherz analysis to assess the skeletal and dental changes with myofunctional therapy by superimposing the tracings (at T0 and T1) on T-FMN line, with T point as the registration point (Figure 3a, b) (16). Ten randomly selected cephalograms were retraced and evaluated by the same examiner (NS) after a week to check for intra-examiner reliability.

2. Esthetic and functional evaluation

a. Preparation of questionnaire

The questionnaire was prepared based on two aspects: measuring esthetic and functional dimensions. Initially, twenty questions from each dimension were generated by a panel of experienced orthodontists (TT & PR) based on a previous similar study (17). Questions which were double negatives, unclear in meaning, and doubtful were removed. Finally, only five questions in each dimension were included (Table 1). Aesthetic acceptance of the subject was evaluated by assessing their routine functions such as smiling and talking to peers. The functional dimension was assessed by chewing efficiency and appliance discomfort.

The esthetic acceptability of CTB and ETB was ascertained by responses to questions 1 to 5 where 1-3 represented consciousness, 4 denoted confidence, and 5 depicted look of the appliance. The response to questions 6 to 10 ascertained the functional efficacy of two appliances.

A five-point Likert scale was used for each question ranging from strong disagreement to strong agreement.

**Table 1.** Questionnaire for esthetic and functional evaluation

| **After wearing the appliance,** |
|---|
| Q1 I can show my teeth while smiling. |
| Q2 I feel people are staring at me. |
| Q3 I am afraid of bullying by my peers. |
| Q4 I avoid looking at myself in the mirror. |
| Q5 I feel satisfied with the look of the appliance. |
| Q 6 It can easily be worn and removed. |
| Q7 It caused discomfort. |
| Q8 It caused difficulty in eating and chewing. |
| Q9 I felt difficulty in speaking. |
| Q10 It fitted in my mouth snugly. |

Likert scale was used for responses as follows: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.

b. Translating the questionnaire
The questionnaire was translated initially from English language to Hindi which was then back translated to English to ensure the accuracy of the translation.

c. Determination of readability
Readability of the questionnaire was assessed using Microsoft Word 2010. Questionnaire had a Flesch Reading Score of 76.9, which is equivalent to a reading age of 12 years. The Flesch-Kincaid Grade Level score (4.5) showed a good level of readability.

d. Test-retest reliability
Each patient was asked to fill the questionnaire in the fourth week of their regular visit regarding their experience with the appliance. The patient filled the same questionnaire in the sixth week in order to assess the test-retest reliability of the questionnaire. Pearson product-moment correlation coefficient was found to be 0.989-1.000, which indicates good test-retest reliability of the questionnaire.

e. Ease of Administration
The questionnaires were checked for completeness and the time taken by each patient to fill the questionnaire was found to be 5-7 min using a stopwatch.



**Table 2.** Comparative cephalometric changes between Conventional (Group 1) and Esthetic (Group 2) twin block groups.

| | Treatment changes | | | | |
|---|---|---|---|---|---|
| | Group 1 (T1-T0) (n=12) | | Group 2 (T1-T0) (n=12) | | Group 1 vs Group 2 |
| **Parameters** | **Mean±SD** | **p** | **Mean±SD** | **p** | **p** |
| Overjet (mm) | -6.54±1.67 | 0.002* | -6.54±1.23 | 0.002* | 0.903 |
| Molar relation (mm) | -6.00±0.85 | 0.002* | -5.79±0.58 | 0.002* | 0.580 |
| Maxillary base (mm) | -0.42±0.51 | 0.025* | -0.63±0.48 | 0.007* | 0.311 |
| Mandibular base (mm) | 2.92 ±0.79 | 0.002* | 4.67 ±0.78 | 0.002* | 0.000* |
| Condylar head (mm) | 0.42±0.67 | 0.059 | -0.17±0.72 | 0.414 | 0.059 |
| Composite mandibular length (mm) | 3.33±1.07 | 0.002* | 4.5±0.52 | 0.002* | 0.006* |
| Maxillary incisor (mm) | -0.92±0.67 | 0.005* | -1.08±0.56 | 0.013* | 0.517 |
| Mandibular incisor (mm) | 2.25±0.50 | 0.001* | 0.17±0.32 | 0.102 | 0.000* |
| Maxillary molar (mm) | -0.42±0.51 | 0.025* | -0.33±0.49 | 0.039* | 0.745 |
| Mandibular molar (mm) | 2.25±0.58 | 0.002* | 0.17±0.32 | 0.102 | 0.000* |
| FMN-T ptba (⁰) | -0.96±0.86 | 0.010* | -0.25±0.62 | 0.180 | 0.048* |
| FMN-T ptar (⁰) | -0.83±1.11 | 0.046* | -0.50±0.80 | 0.206 | 0.206 |
| co-pg (mm) | 4.92±1.73 | 0.002* | 5.5±2.19 | 0.002* | 0.578 |
| co-go (mm) | 2.79±1.5 | 0.002* | 3.17±1.13 | 0.002* | 0.334 |
| go-pg (mm) | 2.79±1.07 | 0.002* | 3.75±1.60 | 0.002* | 0.127 |
| cl-ml (⁰) | 1.17±1.11 | 0.011* | 1.17±0.83 | 0.006* | 0.856 |
| ar-goi-me (⁰) | 1.08±0.79 | 0.003* | 1.00±0.60 | 0.003* | 0.945 |
| nl-(FMN-T line) (⁰) | 0.33±2.35 | 0.565 | 0.25±0.75 | 0.257 | 0.852 |
| ml-(FMN-T line) (⁰) | 1.17±0.54 | 0.002* | 0.88±0.80 | 0.010* | 0.282 |
| nl-ml (⁰) | 0.83±2.24 | 0.210 | 0.63±0.93 | 0.037* | 0.677 |

Superscript (*) indicates significant changes ($p<0.05$).
SD, Standard Deviation; FMN-T ptba, Frontomaxillary nasal suture-tuberculum sella-basion; FMN-T ptar, Frontomaxillary nasal suture-tuberculum sella-articulare; co-pg, condylion-pogonion; co-go, condylion-gonion; go-pg, gonion-pogonion; cl-ml, condylar line-mandibular line; ar-goi-me, articulare-gonion-menton; nl-(FMN-T line), nasal line-(Frontomaxillary nasal suture-tuberculum sella line); ml-(FMN-T line), mandibular line-(Frontomaxillary nasal suture-tuberculum sella line); nl-ml, nasal line-mandibular line.

The content validity of the questionnaire was evaluated by a panel of experienced orthodontists (TT & PR), and it was further checked by test-retest reliability and back translation.

### Statistical Analysis

Data were analyzed using The Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA). Intra-examiner reliability was determined by the intra-class correlation coefficient. Non-parametric tests were employed based on the assessment of normality by the parameters of skewness and kurtosis and the Shapiro-Wilk test. Pre- and post-treatment changes in each group were evaluated using the Wilcoxon matched-pair sign test. Intergroup comparison of pre- and post-cephalometric differences and questionnaire items was evaluated by the Mann-Whitney U test. Statistical significance was set at $p<0.05$.

## RESULTS

No patients dropped out during the study. There was no significant difference in baseline data of G1 and G2 patients. The intra-examiner reliability was found to be 0.997-1.000, which showed very good agreement.

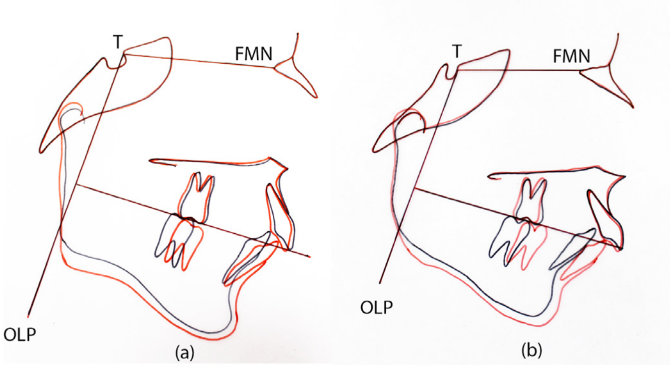


**Figure 4.** Cephalometric tracings superimposition on T-FMN line, (a) CTB, (b) ETB

### Cephalometric Evaluation

The cephalometric superimposition on the T-FMN line for CTB and ETB is shown in Figure 4.

The post-treatment outcome in both groups revealed significant change in overjet reduction, molar relation, movement of the maxillary base, mandibular base advancement, maxillary incisors retroclination, maxillary molars distalization, and increase in composite mandibular length ($p<0.05$) (Table 2).

G1 showed the significant mesial movement of mandibular incisors (2.25 mm; $p<0.05$) and molars ($p<0.05$) whereas insignificant change was observed in G2 (0.17 mm).

Intergroup comparison demonstrated statistically significant mandibular base advancement and composite mandibular length increase in G2 ($p<0.05$) while the change in positions of mandibular incisors ($p<0.05$) and molars ($p<0.05$) were statistically significantly more in G1.

### Esthetic and Functional Evaluation

Based on the responses to the questionnaire, the esthetic and functional efficacy of both appliances was evaluated. Significant differences were observed between the groups for all the questions (Table 3).

Approximately 17% of G1 patients and all the patients of G2 agreed that they can show their teeth while smiling after wearing the appliance. As depicted by the response to questions 2-4, patients of G2 were not conscious and more confident as compared to G1. All the patients in G2 were satisfied with the look of the appliance whereas 75% were dissatisfied in G1 (Table 4).

In G2, all patients experienced the ease of wearing and removal of an appliance whereas 83.33% of G1 patients disagreed. All G2 patients found the appliance to be snuggly fitting and did not experience any discomfort or difficulty in eating, chewing, or speaking. All G1 patients either agreed or were neutral about discomfort and difficulty in speaking and eating while 33.33% felt a snug fit of the appliance (Table 4).

**Table 3.** Likert scale rating of questionnaire

| Questions | Group 1 (n=12) Mean±SD | Group 2 (n=12) Mean±SD | Group 1 vs Group 2 |
|---|---|---|---|
| After wearing the appliance, | | | |
| 1 I can show my teeth while smiling | 2.42±0.79 | 4.75±0.45 | 0.000* |
| 2 I feel people are staring at me | 3.83±0.57 | 1.42±0.67 | 0.000* |
| 3 I am afraid of bullying by my peers | 3.67±0.49 | 1.42±0.51 | 0.000* |
| 4 I avoid looking at myself in the mirror | 3.67±0.49 | 1.42±0.51 | 0.000* |
| 5 I feel satisfied with the look of the appliance. | 2.25±0.45 | 4.17±0.39 | 0.000* |
| 6 It can easily be worn and removed. | 2.08±0.51 | 4.67±0.49 | 0.000* |
| 7 It caused discomfort. | 3.58±0.51 | 1.92±0.67 | 0.000* |
| 8 It caused difficulty in eating and chewing. | 3.83± 0.57 | 1.58±0.51 | 0.000* |
| 9 I felt difficulty in speaking. | 4.00±0.60 | 1.33±0.49 | 0.000* |
| 10 It fitted in my mouth snugly. | 3.25±0.87 | 4.75±0.45 | 0.000* |

Superscript (*) indicates significant changes ($p<0.05$).

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**Table 4.** Percentage of affirmative responses to the questionnaire

| Question | Group | Strongly Disagree | Disagree | Neutral or Unclear | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 75 | 8.33 | 16.67 | 0 |
| | 2 | 0 | 0 | 0 | 25 | 75 |
| 2 | 1 | 0 | 0 | 25 | 66.67 | 8.33 |
| | 2 | 66.67 | 25 | 8.33 | 0 | 0 |
| 3 | 1 | 0 | 0 | 33.33 | 66.67 | 0 |
| | 2 | 58.33 | 41.67 | 0 | 0 | 0 |
| 4 | 1 | 0 | 0 | 33.33 | 66.67 | 0 |
| | 2 | 58.33 | 41.67 | 0 | 0 | 0 |
| 5 | 1 | 0 | 75 | 25 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 83.33 | 16.67 |
| 6 | 1 | 8.33 | 75 | 16.67 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 33.33 | 66.67 |
| 7 | 1 | 0 | 0 | 41.67 | 58.33 | 0 |
| | 2 | 25 | 58.33 | 16.67 | 0 | 0 |
| 8 | 1 | 0 | 0 | 25 | 66.67 | 8.33 |
| | 2 | 41.67 | 58.33 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 16.66 | 66.67 | 16.67 |
| | 2 | 66.67 | 33.33 | 0 | 0 | 0 |
| 10 | 1 | 0 | 16.67 | 50 | 25 | 8.33 |
| | 2 | 0 | 0 | 0 | 25 | 75 |



## DISCUSSION

The present study intends to introduce an esthetically viable, functionally competent twin-block appliance in subjects with Class II malocclusion. With the growing demand for esthetic treatment alternatives, orthodontists are developing appliances which are indiscernible (18, 19). The functional appliances in growing patients are conspicuous and bulky, which often makes the patient reluctant and less compliant towards the treatment (3, 19). Hence, a novel ETB was developed with an intention to overcome these drawbacks of CTB. The concept of ETB formed from the biocryl sheet was based on the study by Bechir et al. (20) who observed better esthetics from biocryl sheet as compared to acrylic resin. Thus, this study was conducted to compare dentoskeletal changes and esthetic and functional efficacy of CTB and ETB. The patients enrolled in the study were in the CVMI transition stage as peak mandibular growth is observed in this stage (21). Further, all patients showed positive VTO where the patients' profile improved by a forward repositioning of the mandible and predicted the likely benefit from functional appliance therapy. Modified Pancherz analysis was used for structural superimposition in both groups for quantitative evaluation of dental and skeletal changes. According to You and Hagg (22), the modified Pancherz method has been observed to be the most suitable amongst all other superimposition methods, viz. Ricketts and Bjork.

Patients treated with CTB showed significant reduction in overjet and change in molar relation but the observed change in both the parameters was equally contributed by skeletal and dental effects (Figure 5) which were commensurable with earlier studies (1, 6, 23). The observed skeletal changes were mainly due to statistically significant increment in mandibular base length (2.92 mm), and the amount of increment in mandibular length (1.46-3.52 mm) also corresponded to previous studies (6-8, 23, 24). Dental changes involving lower incisor proclination and retroclination of maxillary incisors undermine the potential of CTB in achieving the desired skeletal change.

With the use of ETB, a statistically significant reduction in overjet and molar relation were seen which was mainly due to skeletal changes (81%) attributed to significant increment in mandibular base length, whereas no significant change in position of mandibular incisors was seen (Figure 6). The insignificant proclination of lower incisors extended the scope of skeletal correction. The control of the lower incisors proclination could be attributed to the wide coverage of biocryl sheet on all teeth cervically, which further reinforced anchorage, imparting greater stability in the sagittal dimension (25). Skeletal and dentoalveolar contribution to molar relation were almost similar as observed with overjet correction. The increment in mandibular base length (4.67 mm) observed in the present study was greater than that seen in the previous studies involving CTB (6, 7, 23, 24). However, significant retroclination of upper incisors in the ETB group was observed which may possibly be due to a reduction in rigidity caused by splitting of the appliance by expansion screw. Moreover, the retroclination of the upper incisor is desirable and is an advantage in Class II division 1 patients who present with proclined upper anterior teeth (26).

The patient's acceptance and compliance with orthodontic appliances determine their satisfaction while undergoing myofunctional therapy. Hence, the questionnaire was designed to evaluate and compare the patients' experience with CTB and ETB. The questions were composed for easy comprehension and appropriate response by the patients.

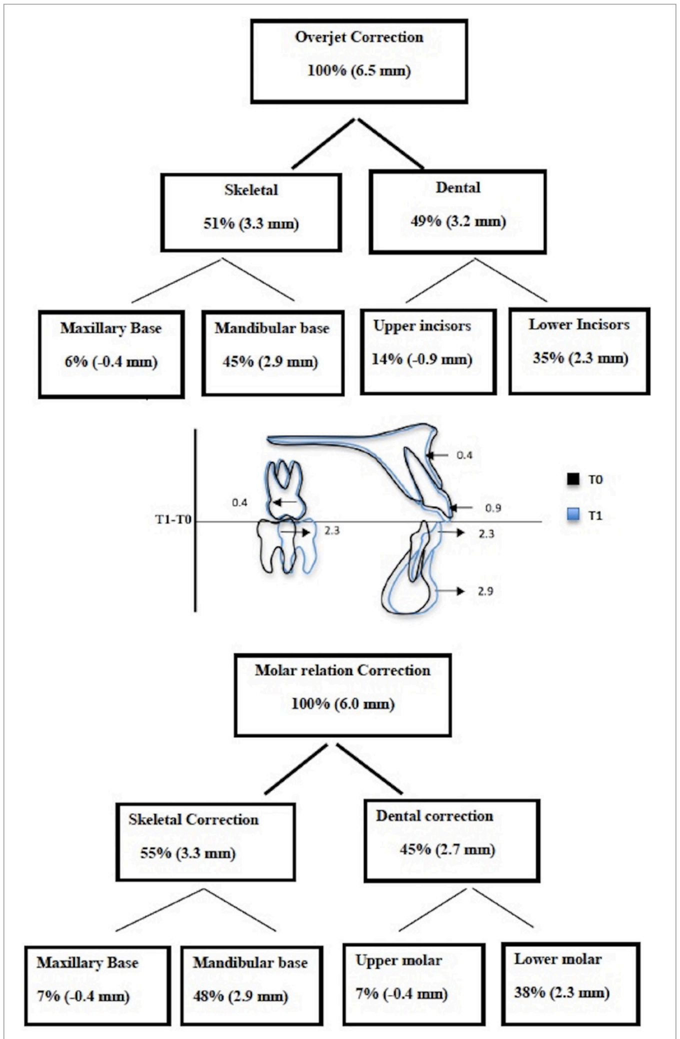


**Figure 5.** Schematic diagram of maxillary and mandibular skeletal and dental changes after CTB

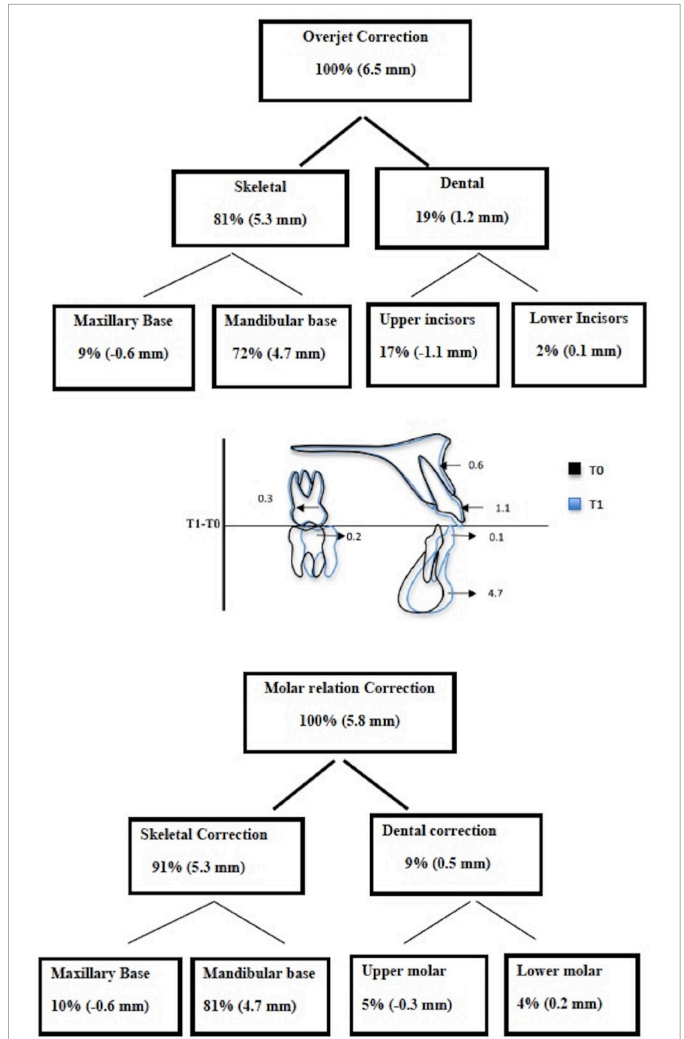


**Figure 6.** Schematic diagram of maxillary and mandibular skeletal and dental changes after ETB

The esthetic assessment revealed the acceptance of the appliance by the patient in terms of consciousness, confidence, and facade of the appliance. ETB was more acceptable to the patients as compared to CTB due to the absence of wire components and transparent biocryl sheet, which rendered it inconspicuous in appearance, leading to reduced apprehension during social interactions. Similar findings were observed by Kumar et al. (27) with Essix retainers.

In our study, the insertion and removal were easier with ETB as compared to the CTB. The functional efficacy is governed primarily by the fit and thickness of the appliance. The complete encapsulation of dentition in ETB and better mechanical properties of thermoformed biocryl sheet over cold cure acrylic resin made it more comfortable during eating and chewing. A similar observation was projected by Sheridan et al.(28) Further, the speech was also not affected which was found to be in accordance with the results of Atik et al. (29), who observed less speech difficulty with Essix retainer as compared to that with Hawley retainers. Moreover, the reduced thickness of the biocryl sheet compared to acrylic in the anterior palatal area causes less change in phonetics (30).

ETB was observed to render better treatment results and was superior with respect to the appearance and functional efficacy of the appliance. Apparently, there was no significant difference in cost-effectiveness between the two appliances. This was a preliminary study of a novel modification, which requires further investigation evaluating gender variation with a larger sample size to corroborate the present results.

## CONCLUSION

A novel appliance for correction of Class II correction in growing patients with better esthetics was studied for its clinical efficacy. It was found to bring about 81% skeletal and 19% dental changes as compared to 51% skeletal and 49% dental changes with CTB. The ETB showed better lower incisor control as compared to CTB. Moreover, ETB was perceived to be superior in terms of esthetics and function in contrast to CTB, which caused greater discomfort and speech interference besides inferior esthetics. Hence, ETB appliance should be preferred over CTB for mandibular advancement in Class II growing patients.

**Ethics Committee Approval:** The study was approved by Institutional research ethical committee of Maulana Azad Institute of Dental Sciences, New Delhi (Reference no. MAIDS 2015).

**Informed Consent:** Written informed consent was obtained from the patients who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Conception - T.T., P.R.; Design - T.T., P.R.; Supervision - T.T.; Data Collection and/or Processing - N.S., P.G.; Analysis and/or Interpretation - T.T., N.S., P.G.; Writing Manuscript - T.T., P.R., N.S., P.G.; Critical Review - T.T., P.R.; Literature Search - N.S., P.G.

**Conflict of Interest:** The authors have no conflict of interest to declare.

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## REFERENCES

1. Sidlauskas A. The effects of the Twin-block appliance treatment on the skeletal and dentolaveolar changes in class II division 1 malocclusion. Medicina (Kaunas) 2005; 41: 392-400.
2. Dauravu LM, Vannala V, Arafath M, Singaraju GS, Cherukuri SA, Mathew A. The assessment of sagittal changes with twin block appliance in patients with decelerating growth phase. J Clin Diagn Res 2014; 8: ZC81-4. [Crossref]
3. Smailienė D, Intienė A, Dobradziejutė I, Kušleika G. Effect of treatment with twin-block appliances on body posture in class II malocclusion subjects: a prospective clinical study. Med Sci Monit 2017; 23: 343-52. [Crossref]
4. Al-Anezi SA. Class II malocclusion treatment using combined twin block and fixed orthodontic appliances - a case report. Saudi Dent J 2011; 23: 43-51. [Crossref]
5. Joss-Vassali I. Orthodontic therapy and gingival recession: a systematic review. OrthodCraniofac Res 2010; 13: 127-41. [Crossref]
6. Baccetti T, Franchi L, Toth LR, McNamara JA Jr. Treatment timing for twin block therapy. Am J Orthod Dentofacial Orthop 2000; 118: 159-70. [Crossref]
7. Toth LR, McNamara JA Jr. Treatment effects produced by the twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated class II sample. Am J Orthod Dentofacial Orthop 1999; 116: 597-609. [Crossref]
8. O'Brien K, Wright J, Conboy F. Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicenter, randomized, controlled trial. Part 1: dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003; 124: 234-43. [Crossref]
9. Trenouth MJ, Desmond S. A randomized clinical trial of two alternative designs of twin-block appliance. J Orthod 2012; 39: 17-24. [Crossref]
10. van der Plas MC, Janssen KI, Pandis N, Livas C. Twin block appliance with acrylic capping does not have a significant inhibitory effect on lower incisor proclination. Angle Orthod 2017; 87: 513-8. [Crossref]
11. Tripathi T, Singh N, Rai P, Gupta P. Mini-implant-supported twin-block appliance: an innovative modification. Niger J Clin Pract 2019; 22: 432-38.
12. Ziuchkovski JP, Fields HW, Johnston WM, Lindsey DT. Assessment of perceived orthodontic appliance attractiveness. Am J Orthod Dentofacial Orthop 2008; 133: 68-78. [Crossref]
13. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofacial Orthop 2009; 135: 276.e1-e12. [Crossref]
14. Jena AK, Duggal R. Treatment effects of twin-block and mandibular protraction appliance-IV (MPA-IV) in the correction of class II malocclusion. Angle Orthod 2010; 80: 485-91. [Crossref]
15. Clark WJ. Twin block functional therapy: applications in dentofacial orthopedics. 2nd ed. London: Mosby; 2002.
16. Franchi L, Baccetti T, McNamara JA, Jr. Treatment and post-treatment effects of acrylic splint Herbst appliance therapy. Am J Orthod Dentofacial Orthop 1999; 115: 429-38. [Crossref]
17. Sergl H, Klages U, Pempera J. On the prediction of dentist-evaluated patient compliance in orthodontics. Eur J Orthod 1992; 14: 463-68. [Crossref]
18. Scott P, Fleming P, DiBiase A. An update in adult orthodontics. Dent Update 2007; 34: 427-36. [Crossref]
19. Livas C. The Hybrid Aesthetic Functional (HAF) appliance: a less visible proposal for functional orthodontics. Case Rep Dent 2013; 298671. [Crossref]
20. Bechir A, Pacurar M, Bechir ES, Comaneanu MR, Cires MC, Maris M, et al. Aesthetic importance of resin based dental materials used for orthodontic appliances. Mater Plast 2014; 51: 57-61.
21. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005; 11: 119-29. [Crossref]
22. You QL, Hägg U. A comparison of three superimposition methods. Eur J Orthod 1999; 21: 717-25. [Crossref]
23. Baysal A, Uysal T. Dentoskeletal effects of twin block and herbst appliances in patients with class II division 1 mandibular retrognathy. Eur J Orthod 2014; 36: 164-72. [Crossref]
24. Tümer N, Gültan AS. Comparison of the effects of mono-block and twin-block appliances on the skeletal and dentoalveolar structures. Am J Orthod Dentofacial Orthop 1999; 116: 460-8. [Crossref]
25. Demira A, Babacanb H, Nalcacıc R, Topcuoglu T. Comparison of retention characteristics of essix and hawley retainers. Korean J Orthod 2012; 42: 255-62. [Crossref]
26. Spalj S, MrozTranesen K, Birkeland K, Katic V, Pavlic A, Vandevska-Radunovic V. Comparison of Activator-Headgear and Twin Block Treatment Approaches in Class II Division 1 Malocclusion. BioMed Res Int 2017; 2017: 4861924. [Crossref]
27. Kumar AG, Bansal A. Effectiveness and acceptability of Essix and Begg retainers: a prospective study. Aust Orthod J 2011; 27: 52-6.
28. Sheridan JJ, Ledoux W, Mcminn R. Essix retainers: fabrication and supervision for permanent retention. J Clin Orthod 1993; 27: 37-45.
29. Atik E, Esen Aydinli F, Kulak Kayikçi ME, Ciger S. Comparing the effects of essix and hawley retainers on the acoustics of speech. Eur J Orthod 2017; 39: 440-5. [Crossref]
30. Wan J, Wang T, Pei X, Wan Q, Feng W, Chen J. Speech effects of hawley and vacuum-formed retainers by acoustic analysis: a single-center randomized controlled trial. Angle Orthod 2017; 87: 286-92. [Crossref]

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Original Article

# Quantitative Comparison of Cephalogram and Cone-Beam Computed Tomography in the Evaluation of Alveolar Bone Thickness of Maxillary Incisors

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## ABSTRACT

**Objective:** This study aims to quantitatively compare cephalogram and cone-beam computed tomography (CBCT) when evaluating maxillary central incisor alveolar bone thickness.

**Methods:** We used 30 sets of lateral cephalograms and CBCT images that were recorded at the same time. Labial, buccal, and overall alveolar bone thicknesses were measured on three measurement lines of the forward-most incisor in lateral cephalograms and four maxillary incisors in CBCT images. Paired t-test, interclass correlation coefficient analysis, one-way analysis of variance (ANOVA), and Bland–Altman analysis were used to assess cephalometrically measured alveolar bone thickness of maxillary incisors and compare these measurements with those made using CBCT images.

**Results:** Significant differences were observed between cephalometric and CBCT-based measurements of maxillary incisor alveolar bone thickness; most values showed mild or moderate correlation between the two methods. In most cases, cephalometric measurements were greater than CBCT-based measurements. Bland–Altman plots and ANOVA revealed that measurement bias increased when measurement lines moved apically. Alveolar bone thickness was always overestimated on cephalograms.

**Conclusion:** Maxillary incisor alveolar bone thickness is always overestimated on cephalograms compared with CBCT-based measurements, with the overestimations ranging from 0.3 to 1.3 mm. Cephalometric measurement bias increases when measurement lines move apically. Thus, CBCT should be recommended when the accurate evaluation of alveolar bone thickness is warranted.

**Keywords:** Alveolar bone thickness, cephalogram, cone-beam computed tomography, maxillary incisor, orthodontic diagnosis

Main points:

- Maxillary incisor alveolar bone thickness is always overestimated on cephalograms compared with CBCT-based measurements.
- Cephalometric measurement bias increases when measurement lines move apically.
- CBCT should be recommended when the accurate evaluation of alveolar bone thickness is warranted.

## INTRODUCTION

Lateral cephalogram is an essential and irreplaceable tool in clinical and academic orthodontics that provides elaborate information for diagnosis and treatment planning (1). With the advent of computed tomography technology, cone-beam computed tomography (CBCT) is gaining popularity as a promising modality in dental practice, with several obvious advantages compared with two-dimensional (2D) cephalograms.

CBCT images provide three-dimensional (3D) assessment of the life-size craniofacial complex without distortion or overlapping of anatomical structures (2-4). In addition, it provides a highly accurate method to evaluate bony architecture and has been previously used to quantify facial bone for orthodontic research as well as to measure bone volume following regenerative periodontal therapy (5, 6). CBCT scans may help in planning treatment,

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particularly for implant placement of the maxillary aesthetic region, because they can contribute to predictions of some possible pre- or post-surgical soft or hard tissue complications (7). Therefore, CBCT is the preferred measurement technique for determining alveolar bone thickness.

Extensive research has been conducted to investigate the accuracy and consistency of craniofacial measurements recorded using these two methods. Generally, CBCT images provide more precise identification of traditional cephalometric landmarks (8, 9), and in a clinical setting they provide more accurate and reliable 3D and linear measurements of the craniofacial complex (10-12).

In addition, CBCT can be used to evaluate alveolar thickness. The thickness of the supporting alveola is a critical issue that must be considered during orthodontic treatment, particularly when treating maxillary incisors, which always need a wide range of labiopalatal movement. According to Yodthong et al. (13), the rate of tooth movement, change in inclination, and extent of intrusion are significant factors that may influence alveolar bone thickness during upper incisor retraction. Ignorance of alveolar bone thickness along with wide tooth movement range may contribute to increased risk of bone fenestration and dehiscence. Therefore, these factors must be carefully monitored.



Although CBCT provides a relatively more reliable method to evaluate alveolar thickness, it is not routinely prescribed because of the radiation dose used and its cost. Most orthodontists use only lateral cephalograms to evaluate maxillary incisor alveolar thickness. However, there is limited clinical research regarding the accuracy of alveolar bone thickness measurements obtained by cephalograms as well as limited research involving the quantitative comparison of cephalograms and CBCT. Therefore, we must determine whether using cephalograms to measure maxillary incisor alveolar bone thickness in orthodontic treatment is reasonable and whether CBCT should be routinely prescribed for this purpose.

Herein, we aim to quantitatively compare cephalogram and CBCT for evaluating maxillary central incisor alveolar bone thickness. The findings of this study will enrich and expand the knowledge regarding whether and when CBCT is required to evaluate anterior maxillary alveolar bone thickness.

## METHODS

### Subjects

The study was approved by the local ethics committee of Peking University School of Stomatology, Beijing, China (PKUSSIRB-201838113). A total of 30 sets of CBCT images and cephalograms (13 men, 17 women; age, 18.9±6.02 years) were selected from the Department of Orthodontics, Peking University School of Stomatology. The exclusion criteria were as follows: cleft palate; missing or supernumerary anterior teeth; rotated, tipped, or torqued teeth; periodontal disease; deciduous anterior teeth; and other pathological manifestations of anterior teeth. CBCT images and lateral cephalograms were obtained on the same day. All the images were taken for the clinical orthodontic treatment.

### Imaging and Processing

Lateral cephalograms were obtained using an orthopantomograph equipped with a cephalostat (Orthopantomograph® OP200 D, Instrumentirium Corp, Graven, Finland) with the following parameters: 77 kV, 16 mA, and exposure time of 0.63–1.0 seconds. The measurements were made using Photoshop 7.0 (Adobe® Systems, San Jose, CA).

CBCT images were obtained using the NewTom CBCT system (NewTom VG, Quantitative Radiology, Verona, Italy) with the following parameters: 120 kV; exposure time, 3.6 seconds; and axial thickness, 0.200 mm. The measurements from CBCT images were made using Ondemand3D (Cybermed, Seoul, Korea). The center of each tooth was measured on the sagittal plane.

### Measurements

On the lateral cephalograms, the measurements were converted to 100% magnification. The scale ruler on the cephalogram was used to perform the mathematical conversion. Outlines of the most anterior part of the maxillary alveolar plates and maxillary incisor are shown in Figure 1. Four reference lines were used, which were perpendicular to the long axis of the upper incisor. Line A was drawn at the labial alveolar crest, line B was drawn 2.4 mm apically to line A, line C was 4.8 mm off, and line D was 7.2 mm off. The thicknesses of labial, palatal, and labiopalatal (overall) alveolar plates were measured at lines B, C, and D, respectively. Lines B, C, and D were selected to roughly represent crestal, mid-root, and apical levels of maxillary incisors, respectively.

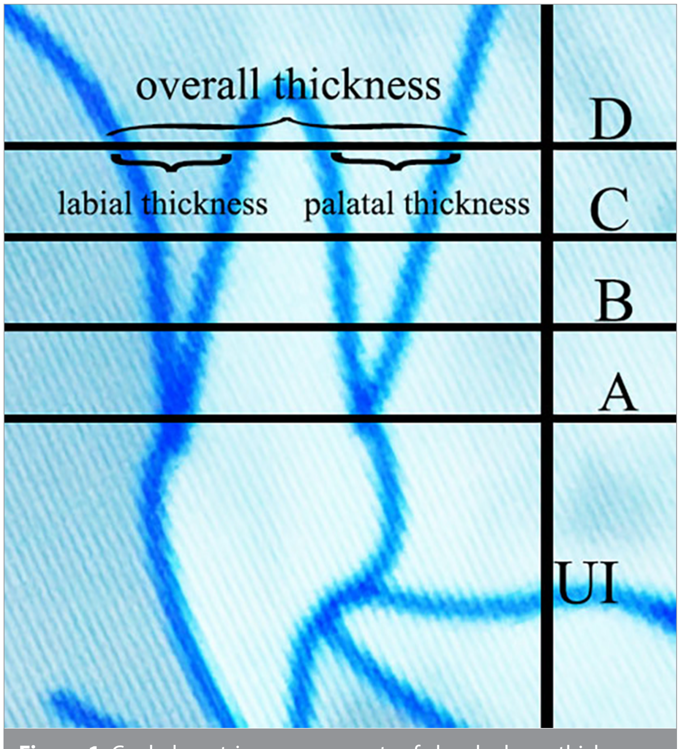


**Figure 1.** Cephalometric measurements of alveolar bone thickness Labial, palatal and overall thickness were all measured on lines B, C and D

On CBCT images, the mid-sagittal plane of each maxillary incisor was chosen as a reference line and the same measurements were made in each image (Figure 2).

An experienced clinical orthodontist from the Department of Orthodontics, Peking University School of Stomatology, performed all sets of digital measurements twice, with an interval of 1 week between the measurements.

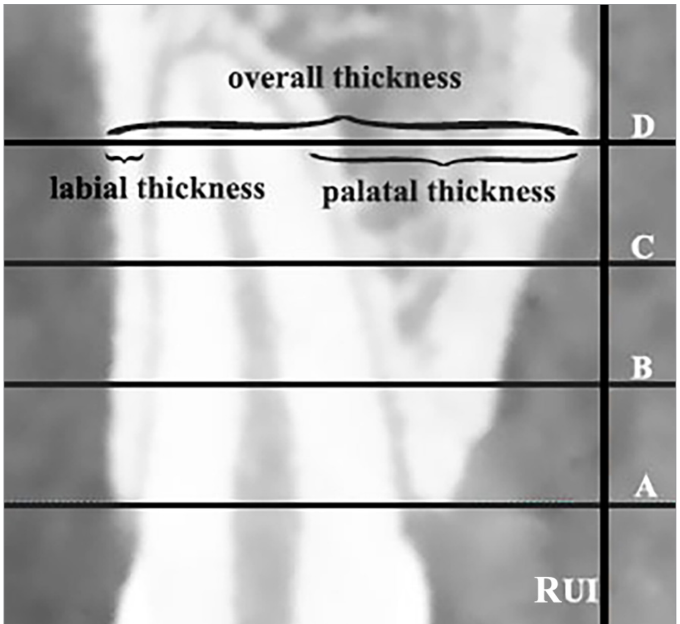


**Figure 2.** Measurements of alveolar bone thickness on a CBCT image. Same reference lines were used and same measurements were made on CBCT for all four incisors.

**Table 1.** Paired t-test for repeated measurements (mm) on cephalograms and CBCT (n=30)

| Measurements | Mean | Std deviation | p |
|---|---|---|---|
| Cephalograms | -0.008 | 0.75 | 0.854 |
| CBCT-based | -0.011 | 0.74 | 0.820 |

Std deviation: standard deviation.

### Statistical Analysis

Paired t-tests, interclass correlation coefficient (ICC) analysis, and Dahlberg's formula were used to investigate the reproducibility of the operator's measurements and to perform comparisons between the measurement methods. Kolmogorov–Smirnov normality tests revealed that the data conformed to a normal distribution in all measurement areas. Mean value, standard deviation (SD), correlation analysis, and one-way analysis of variance (ANOVA) were used to identify the relationship between cephalometric and CBCT-based measurements. The significance level was set at $p=0.05$. These tests were performed using Statistical Package for Social Sciences software version 21 (IBM Corp.; Armonk, NY, USA). Bland–Altman analysis was used to assess the agreement of cephalometric and CBCT-based measurements, which were generated using MedCalc software (version 17.9.7; MedCalc Software, Mariakerke, Belgium).

## RESULTS



No statistically significant differences were observed between the two repeated measurements on cephalograms as well as on CBCT images (Table 1, $p>0.05$). The average values of the two measurements were used.

Table 2 presents descriptive statistics of the differences that were always smaller in the central incisors. All labial bone thickness measurements, most palatal measurements, and overall thickness revealed highly significant differences between cephalometric and CBCT-based measurements.

Table 3 presents the correlation analysis. All ICCs of labial and palatal thickness were <0.50 mm, and most ICCs ranged in overall thickness from 0.40 to 0.70. Thus, the correlation between cephalometric and CBCT-based measurements was not sufficiently strong.

**Table 2.** Quantitative comparisons between cephalometric and CBCT-based measurements (mm)

| | | Labial | | | Palatal | | | Overall | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reference Line | | ΔMean | SD | p | ΔMean | SD | p | ΔMean | SD | p |
| B | 11 | 0.33 | 0.32 | <0.001** | 0.28 | 0.94 | 0.118 | -1.24 | 0.80 | 0.401 |
| | 21 | 0.29 | 0.33 | <0.001** | 0.50 | 0.82 | 0.002** | 0.01 | 0.73 | 0.925 |
| | 12 | 0.46 | 0.41 | <0.001** | 0.71 | 1.15 | 0.002** | 0.46 | 0.80 | 0.004** |
| | 22 | 0.30 | 0.53 | 0.004** | 0.60 | 1.15 | 0.007** | 0.51 | 0.91 | 0.005** |
| C | 11 | 0.55 | 0.48 | <0.001** | 0.40 | 1.05 | 0.047* | 0.31 | 0.81 | 0.047* |
| | 21 | 0.48 | 0.48 | <0.001** | 0.74 | 0.93 | <0.001** | 0.48 | 0.80 | 0.002** |
| | 12 | 0.76 | 0.49 | <0.001** | 0.89 | 1.37 | 0.001** | 0.88 | 1.00 | <0.001** |
| | 22 | 0.68 | 0.51 | <0.001** | 0.83 | 1.31 | 0.002** | 1.06 | 1.04 | <0.001** |
| D | 11 | 0.98 | 1.03 | <0.001** | -0.30 | 2.02 | 0.935 | 0.80 | 1.31 | 0.002** |
| | 21 | 0.93 | 0.98 | <0.001** | 0.28 | 1.59 | 0.349 | 1.05 | 1.18 | <0.001** |
| | 12 | 1.31 | 0.94 | <0.001** | 0.29 | 1.83 | 0.393 | 1.20 | 1.44 | <0.001** |
| | 22 | 1.27 | 0.78 | <0.001** | 0.47 | 1.64 | 0.130 | 1.51 | 1.50 | <0.001** |

ΔMean: cephalometric measurements (labial\palatal\overall thickness on line B\C\D of the most forward incisor in cephalograms) minus; CBCT-based measurements (labial\palatal\overall thickness on line B\C\D of the four incisors in CBCT); SD: standard deviation; 11\21\12\22, right central incisor\left central incisor\ right lateral incisor\ left lateral incisor; **: p<0.01, statistically highly significant; *: p<0.05, statistically significant.

**Table 3.** Correlation coefficient (r) and Interclass Correlation Coefficient (ICC) between cephalometric and CBCT-based measurements

| | | Labial | | | | Palatal | | | | Overall | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference Line | | r | p | ICC | p | r | p | ICC | p | r | p | ICC | p |
| B | 11 | 0.405 | 0.026 | 0.250 | 0.013 | -0.042 | 0.824 | -0.042 | 0.589 | 0.417 | 0.022 | 0.417 | 0.010 |
| | 21 | 0.346 | 0.061 | 0.231 | 0.030 | 0.202 | 0.283 | 0.201 | 0.140 | 0.539 | 0.002 | 0.539 | 0.001 |
| | 12 | 0.181 | 0.338 | 0.091 | 0.165 | -0.248 | 0.186 | -0.236 | 0.899 | 0.303 | 0.104 | 0.295 | 0.053 |
| | 22 | 0.438 | 0.015 | 0.310 | 0.021 | -0.106 | 0.579 | -0.97 | 0.699 | 0.403 | 0.027 | 0.396 | 0.014 |
| C | 11 | 0.060 | 0.753 | 0.055 | 0.385 | 0.115 | 0.543 | 0.111 | 0.276 | 0.579 | 0.001 | 0.579 | <0.001 |
| | 21 | 0.096 | 0.613 | 0.090 | 0.315 | 0.330 | 0.075 | 0.317 | 0.041 | 0.626 | <0.001 | 0.623 | <0.001 |
| | 12 | 0.049 | 0.796 | 0.046 | 0.403 | -0.008 | 0.967 | -0.007 | 0.514 | 0.349 | 0.059 | 0.349 | 0.027 |
| | 22 | 0.259 | 0.166 | 0.295 | 0.079 | 0.190 | 0.314 | 0.158 | 0.197 | 0.482 | 0.007 | 0.466 | 0.004 |
| D | 11 | -0.203 | 0.283 | -0.017 | 0.820 | 0.006 | 0.973 | 0.010 | 0.490 | 0.595 | 0.001 | 0.562 | 0.001 |
| | 21 | -0.193 | 0.307 | -0.146 | 0.784 | 0.278 | 0.137 | 0.233 | 0.104 | 0.613 | <0.001 | 0.596 | <0.001 |
| | 12 | -0.003 | 0.989 | -0.002 | 0.505 | 0.196 | 0.299 | 0.153 | 0.205 | 0.455 | 0.012 | 0.437 | 0.007 |
| | 22 | 0.409 | 0.025 | 0.362 | 0.023 | 0.309 | 0.097 | 0.251 | 0.087 | 0.519 | 0.003 | 0.478 | 0.003 |

r: correlation coefficient; ICC: Interclass Correlation Coefficient; 11\21\12\22, right central incisor\left central incisor\ right lateral incisor\ left lateral incisor.



**Table 4.** Comparison of absolute value of the difference between cephalometric and CBCT-based measurements on three reference lines

| | | 11 | 21 | 12 | 22 |
|---|---|---|---|---|---|
| Labial | B | b | b | c | b |
| | C | ab | b | b | b |
| | D | a | a | a | a |
| Palatal | B | b | b | b | a |
| | C | b | a | a | a |
| | D | a | ab | ab | a |
| Overall | B | b | b | b | c |
| | C | ab | ab | a | b |
| | D | a | a | a | a |

a\b\c\d: subgroups of multiple comparisons; Subgroup 'a' had the greatest absolute values of difference, and different letters showed statistical significance between group. Measurements with the same subgroup letter do not differ significantly for multiple comparisons. 11\21\12\22: right central incisor\ left central incisor\ right lateral incisor\ left lateral incisor; B: measurements on reference line B; C: measurements on reference line C; D: measurements on reference line.

One-way ANOVA was used to assess the differences among the three measurement lines. Table 4 summarizes the results of this analysis. The absolute value of difference was analyzed, and the subgroup measurements indicated that differences increased when measurement lines moved apically.

In Bland–Altman plots, the limits of agreement were defined as±1.96 SD. The 95% limits of agreement were 0.4±1.60 (mean±1.96 SD), 0.7±1.80, and 0.8±2.90 mm for lines B, C, and D, respectively (Figure 3).

## DISCUSSION

Ignoring high-risk periodontal conditions and inappropriate tooth movement can have negative iatrogenic effects on orthodontic treatment, including root resorption, artificial bone defects, gingival recession, and unexpected progressing tooth mobility (14).

Artificial bony defects such as fenestration and dehiscence are gaining more attention with the development of CBCT (15). Krishna et al. (16) reported that when incisors were retracted, a few patients demonstrated bone dehiscence, which was not visible macroscopically or cephalometrically. Meanwhile, some defects are inherent. Gang et al. (17) reported that the incidence of bone fenestration and dehiscence in the incisor region of skeletal Class II division 1 malocclusions was 30.78% and 36.15%, respectively, in Chinese individuals, and the left upper central incisor was the second-most commonly affected tooth with fenestration.

For orthodontists to accurately plan treatments and ensure positive outcomes, full-scale and accurate assessment of maxillary incisor alveolar bone thickness is highly important. Many researchers have measured maxillary incisor alveolar thickness using CBCT images, particularly in implant procedures. Fuentes et al. (18) evaluated the bone buccal to maxillary incisors and found that <10% sites showed more than a 2-mm thickness of the buccal bone wall. Lee et al. (19) measured the thickness of buccal and palatal alveolar plates of maxillary incisors in a Korean subpopulation using CBCT images and reported that the anterior buccal plate was very thin, within 1 mm, and the thickness of the palatal plate was relatively thick. Therefore, maxillary incisor alveolar bone thickness must be considered in orthodontic treatments.

Several researchers have investigated the diagnostic validity of lateral cephalograms in terms of alveolar bone thickness, but most of them have only focused on labial/buccal alveolar plates. Kula et al. (20) showed that the thickness of the bone buccal to root apices of the most forward maxillary incisor is greater when measured on 2D cephalograms than that measured on 3D CBCT images.

In addition to labial bone thickness, palatal and overall alveolar bone thicknesses are equally important. Thongudomporn et al. (21) reported statistically significant decreases in palatal and over-

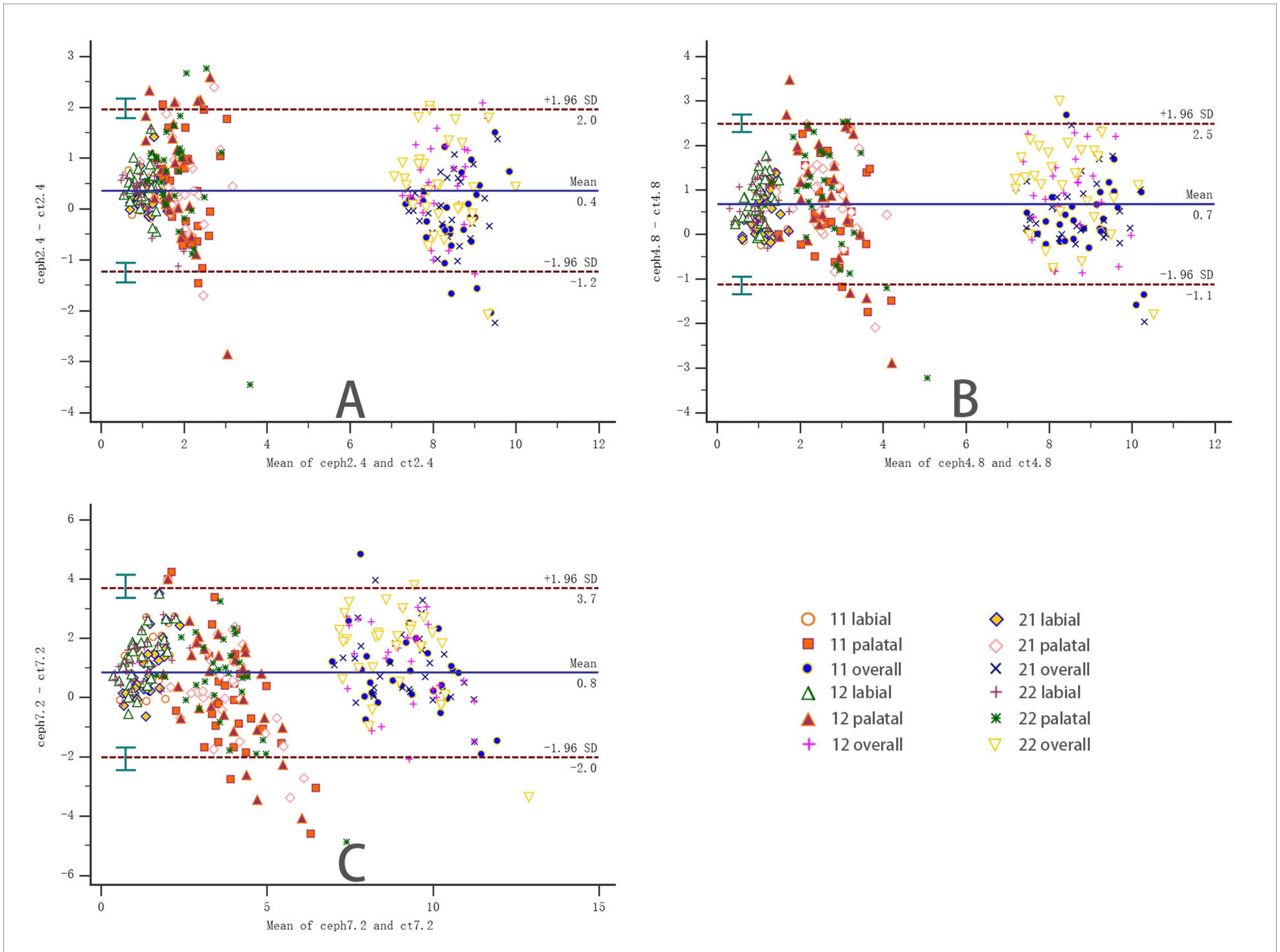


**Figure 3.** Bland-Altman analysis: difference against the mean (thick solid blue line in the middle) of cephalometric (ceph) and CBCT-based measurements
A: measurements on line B; B: measurements on line C; C: measurements on line D.

all bone thicknesses at mid-root and apical levels after maxillary incisors were proclined and extruded in a group of patients with Class III malocclusion. In fact, labial and lingual cortical plates at the level of the apex of an incisor may represent the anatomic limits of tooth movement (22). Thus, palatal as well as overall alveolar bone thicknesses of maxillary incisors must be evaluated.

Because labial, palatal, and overall alveolar bone thicknesses of maxillary incisors are highly important during orthodontic treatment planning, orthodontists must determine whether cephalograms accurately reflect bone thickness in comparison with CBCT. Thus, in the present study, labial, palatal, and overall thicknesses were measured on three reference lines on both lateral cephalograms and CBCT images.

Cephalometric measurements were greater than CBCT-based measurements in most cases (Table 2), indicating that perhaps alveolar bone thickness is always overestimated on cephalograms. The differences were highly significant between cephalometric and most CBCT values (Table 2). Moreover, the mean values of different measurements increased apically and were always smaller for central incisors than those for lateral ones. Furthermore, simple correlation analysis and ICC were conducted (Table 3), wherein most values showed mild or moderate correlation between cephalometric and CBCT-based measurements.

Lee et al. (23) suggested that the following three conditions must be met to conclude that the two methods for measuring a quantitative variable are interchangeable: 1) the methods must not exhibit marked additive or nonadditive systematic bias; 2) the difference between the two mean readings should not be statistically significant; and 3) the lower limit of 95% confidence interval of ICC should be at least 0.75 (indicating that there is a strong or very strong correlation). Thus, it can be easily concluded that cephalometric measurements were not interchangeable with CBCT-based measurements. Moreover, owing to the limitations of 2D imaging techniques, such as overlapping of anatomical structures, cephalometric measurements do not always reflect the actual measurements (24).

Measuring at three different levels was one of the advantages of the study. Of these locations, the crestal position may contribute most to the aesthetic problems because the crestal bone supports the gingival margin and resorption of bony structure leads to mucosal recession. The mid-root and apical positions are of equal importance; these can help clinicians to be aware of how teeth move as well as the torque used on maxillary incisors.

In Bland–Altman analysis (Figure 3), the measurements on line B showed the smallest mean differences and relatively small limits of agreement (0.4±1.60 mm), whereas the measurements on line D showed the largest mean differences (0.8±2.9 mm). This might be due to the overlap of the more complex anatomical structures when measurements lines were moved apically.

One-way ANOVA (Table 4) was conducted to compare measurements on different lines. Subgroup "a" had the greatest absolute values of difference. The measurements on line D had the greatest absolute difference, and in most cases, values on line B were significantly less different than those on line D. Thus, the accuracy of measurements decreased when measurement lines were moved apically. Clinicians should pay careful attention to alveolar bone thickness of the apical third of the root, particularly when the apices of incisors need a wide range of movement, and CBCT should be recommended in such cases.



A study has showed limitations for using CBCT to assess bone thickness, especially in thin bone areas such as the overestimation of bone dehiscence and fenestration (25). However, there is no gold standard to assess the alveolar bone thickness in these studies, and CBCT is a relatively more accurate method compared with conventional 2D radiographs (26).

A limitation to our study is that we examined generally healthy patients. The cephalometric measurement bias would therefore increase when the situation becomes more complicated such as in patients who meet the exclusion criteria. Skeletal discrepancy influences the inclination of the maxillary and mandibular incisors, which can influence the thickness of labial alveolar bone (27), and this factor can be considered in future studies. More attention should be paid to alveolar bone thickness in orthodontic treatment.

## CONCLUSION

Maxillary incisor alveolar bone thickness is always overestimated in cephalograms compared with CBCT-based measurements. This overestimation ranges from 0.3 to 1.3 mm. Cephalometric measurement bias increases when measurement lines move apically. Therefore, CBCT should be recommended when the accurate evaluation of alveolar bone thickness is warranted.

**Ethics Committee Approval:** This study was approved by Ethics committee of Peking University School of Stomatology, Beijing, China (Approval No: PKUSSIRB-201838113).

**Informed Consent:** Verbal informed consent was obtained from the patients who agreed to take part in the study.

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**Conflict of Interest:** The authors have no conflict of interest to declare.

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## REFERENCES

1. da Silva MB, Gois BC, Sant'Anna EF. Evaluation of the reliability of measurements in cephalo-grams generated from cone beam computed tomography. Dental Press J Orthod 2013; 18: 53-60. [Crossref]
2. Moreira CR, Sales MA, Lopes PM, Cavalcanti MG. Assessment of linear and angular measure-ments on three-dimensional cone-beam computed tomographic images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108: 430-6. [Crossref]
3. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. Am J Orthod Dentofacial Orthop 2009; 136: 19-25. [Crossref]
4. Lagravère M O, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2008; 134: 112-6. [Crossref]
5. Rungcharassaeng K, Caruso JM, Kan JYK, Kim J, Taylor G. Factors affecting buccal bone chang-es of maxillary posterior teeth after rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2007; 132: 428.e1-8. [Crossref]
6. Grimard BA, Hoidal MJ, Mills MP, Mellonig JM, Nummikoski PV, Mealy BL. Comparison of clinical, periapical radiograph, and cone-beam volume tomography measurement techniques for as-sessing bone level changes following regenerative periodontal therapy. J Periodontol 2009; 80: 48- 55. [Crossref]
7. Nowzari H, Molayem S, Chiu CH, Rick SK. Cone beam computed tomographic measurement of max-illary central incisors to determine prevalence of facial alveolar bone width ≥2 mm. Clin Implant Dent Relat Res 2012; 14: 595-602. [Crossref]
8. Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: cone-beam computed tomography vs conventional cephalometric views. Am J Orthod Dentofacial Orthop 2009; 136: 312.e1-10. [Crossref]
9. Nowzari H, Molayem S, Chiu CH, Rich SK. Cone beam computed tomographic measurement of maxillary central incisors to determine prevalence of facial alveolar bone width ≥2 mm. Clin Implant Dent Relat Res 2012; 14: 595-602. [Crossref]
10. Berco M, Jr Rigali PH, Miner RM, DeLuca S, Anderson NK, Will LA. Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. Am J Orthod Dentofacial Or-thop 2009; 136: 17-8. [Crossref]
11. Chien PC, Parks ET, Eraso F, Hartsfield JK, Roberts WE, Ofner S. Comparison of reliability in anatomical landmark identifica-tion using two-dimensional digital cephalometrics and three-dimensional cone beam computed tomog-raphy in vivo. Dentomaxillofac Radiol 2009; 38: 262-73. [Crossref]

12. de Oliveira AE, Cevidanes LH, Phillips C, Motta A, Burke B, Tyndall D. Observer reliability of three-dimensional cepha-lometric landmark identification on cone-beam computerized tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 107: 256-65. [Crossref]
13. Yodthong N, Charoemratrote C, Leethanakul C. Factors related to alveolar bone thickness during upper incisor retraction. Angle Orthodontist 2013; 83: 394. [Crossref]
14. Chan E, Dalci O, Petocz P, Papadopoulou AK, Darendeliler MA. Physical properties of root cementum: part 26. Effects of micro-osteo-perforations on orthodontic root resorption: a microcom-puted tomography study. Am J Orthod Dentofacial Orthop 2018; 153: 204-13. [Crossref]
15. Fuhrmann R. Three-dimensional interpretation of labiolingual bone width of the lower incisors. Part II. J Orofac Orthop 1996; 57: 168-85. [Crossref]
16. Nayak Krishna US, Shetty A, Girija MP, Nayak R. Changes in alveolar bone thickness due to retrac-tion of anterior teeth during orthodontic treatment: a cephalometric and computed tomography com-parative study. Indian J Dent Res 2013; 24: 736-41. [Crossref]
17. Yan Z, Zhenyu Q, Lin L, Wei H, Gang L. The incidence of fenestration and dehis-cence on in-cisor region of Skeletal Class II Division 1 malocclusions: a cone beam CT study. Chinese J Orthodol 2016; 23: 2-7.
18. Fuentes R, Flores T, Navarro P, Salamanca C, Beltrán V, Borie E. Assessment of buccal bone thickness of aesthetic maxillary region: a cone-beam computed tomography study. J Periodontal Implant Sci 2015; 45: 162-8. [Crossref]
19. Lee SL, Kim HJ, Son MK, Chung CH. Anthropometric analysis of maxillary anterior buccal bone of Korean adults using cone-beam CT. J Adv Prosthodont 2015; 2: 92-6. [Crossref]
20. Kula T J, Ghoneima A, Eckert G, Parks ET, Utreja A, Kula K. Two-dimensional vs 3-dimensional comparison of alveo-lar bone over maxillary incisors with A-point as a reference. Am J Orthod Dentofacial Orthop 2017; 152: 836-47.e2. [Crossref]
21. Thongudomporn U, Charoemratrote C, Jearapongpakorn S. Changes of anterior maxillary alveo-lar bone thickness following incisor proclination and extrusion. Angle Orthod 2014; 85: 549-54. [Crossref]
22. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod 1996; 2: 95-110.
23. Lee J, Koh D, Ong CN. Statistical evaluation of agreement between two methods for measuring a quantitative variable. Comput Biol Med 1989; 19:61-70. [Crossref]
24. Kim Y J, Lim S H, Gang S N. Comparison of cephalometric measurements and cone-beam com-puted tomography-based measurements of palatal bone thickness. Am J Orthod Dentofacial Orthop 2014; 145: 165-72. [Crossref]
25. Sun L, Zhang L, Shen G, Wang B, Fang B. Accuracy of cone-beam computed tomography in-detecting alveo-lar bone dehiscences andfenestrations. Am J Orthod Dentofacial Orthop 2015; 147: 313-23. [Crossref]
26. Carlos FM, Rosenblatt MR, Major PW, Carey JP, Heo G. Measurement accuracy and reliability of tooth length on conventional and CBCT reconstructed panoramic radiographs. Dental Press J Orthod 2014; 19: 45-53. [Crossref]
27. Raber A, Kula K, Ghoneima A. Three-dimensional evaluation of labial alveolar bone overlying the maxillary and mandibular incisors in different skeletal classifications of malocclusion. Int Orthod 2019; 17: 287-295. [Crossref]

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Original Article

# Low-Viscosity Resin Infiltration Efficacy on Postorthodontic White Spot Lesions: A Quantitative Light-Induced Fluorescence Evaluation

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## ABSTRACT

**Objective:** The aim of this *in vivo* study was to evaluate the efficacy of low-viscosity light-cured resin infiltration on postorthodontic white spot lesions (WSLs) on incipient and advanced lesions using quantitative light-induced fluorescence (QLF).

**Methods:** The study subjects were patients with clinically diagnosed postorthodontic WSLs (n=57). QLF images of the lesions were obtained using a QLF device (Inspektor-Pro, Amsterdam, The Netherlands) before any treatment. Images were processed using the built-in software (QLF patient v2.0.0.48), which produced fluorescence loss ($\Delta F^1$), lesion area ($Area^1$), and impact ($\Delta F_1$ x $Area_1$, $\Delta Q_1$) values. Lesions were categorized as incipient ($-5<\Delta F_1<-12$, n=14) or advanced ($-12<\Delta F_1<-25$, n=43). They were then infiltrated with low-viscosity resin (Icon-DMG, Hamburg, Germany) according to the manufacturer's instructions. QLF imaging was repeated ($\Delta F_2$, $Area_2$, and $\Delta Q_2$) from the same aspects assured by the relative software. Kolmogorov-Smirnov, Wilcoxon, and Mann-Whitney tests were used for data evaluation.

**Results:** $\Delta F_1$ (−8.40±0.73) and $Area_1$ (3.44±5.19) decreased to −6.58±0.88 and 0.18±0.33 for incipient lesions (p<0.001 and p=0.002, respectively). $\Delta F_1$ (−13.20±5.32) and $Area_1$ (4.71±5.56) decreased to −7.51±2.7 and 0.29±1.86 for advanced lesions (p<0.001). When ΔF, lesion area, and ΔQ changes between the groups were compared, the decrease in ΔF was greater for advanced lesions (p<0.001), whereas the decrease in the lesion area and ΔQ was similar (p=0.690, p=0.291).

**Conclusions:** Infiltration treatment provides improvement of WSLs in terms of fluorescence loss, lesion area, and impact for both incipient and advanced lesions, with the latter group presenting higher fluorescence loss reduction.

**Keywords:** Dental white spots, icon infiltrant, quantitative light-induced fluorescence

## INTRODUCTION

White spot lesions (WSLs) are one of the initial clinical findings of enamel demineralization, resulting from cariogenic bacterial metabolism acting on the tooth surface (1). The risk of WSL formation increases during orthodontic treatment as a consequence of plaque retention sites (2). The individual factors that determine the prognosis of such lesions are the efficacy of personal oral hygiene, saliva buffering capacity, salivary flow rate (3), and the presence of local fluoride (4).

WSLs appear mostly opaque-white due to the changes in the refractive index of the enamel, which are caused by mineral loss from the surface and deeper layers (5). In early stages, WSLs require air drying to become visible. At this stage, demineralization at the outer layer of enamel begins. Progression of this process results in a visible WSL even without air drying. The clinical appearance of a WSL is also related to its activity. Active lesions appear chalky and feel rough during light probing whereas inactive lesions are bright on the outside and feel smooth during probing (6).

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The progression of WSLs can be detained or even arrested by preventive measures such as oral hygiene education, dietary control, and local fluoridation (7). These are the primary choices of treatment, because they promote natural repair and prevention. Even though it has been claimed that these lesions could regress following preventive measures, varying clinical results have been reported that have questioned the predictability of the remineralization process (6, 8, 9). Many early incipient lesions were still visible after remineralization because most of the loss was at the center body of the lesion, where improvement in its light refraction was unlikely due to the limited remineralization potential (10). This type of remineralization results in a shiny and less obvious lesion, but the interior opacity remains. With non-compliant patients, this approach is often ineffective and the lesions tend to progress (6).

In 2009, the low-viscosity resin infiltration technique, which aims to fill the microporosities in the lesion body with a minimally invasive approach, was introduced (11). This resin connects and strengthens the affected tissue micromechanically and stabilizes the demineralized enamel against new acid attacks. Thus, the affected tissue is preserved and the gap between restorative treatment and preventive measures is principally closed (12). This technique is claimed to be suitable for noncavitated lesions that are unlikely to remineralize (13). Moreover, the refractive index of the infiltrant is defined as being similar to the sound enamel, which also provides the visual masking of the lesion (12).

Detection and diagnosis of WSLs can be performed using different methods. Quantitative light-induced fluorescence (QLF) is 1 of the diagnostic methods that can quantify the fluorescence difference between sound and demineralized enamel utilizing light refraction from affected dental surfaces (14-16). Previous studies have demonstrated that this method is reliable to monitor the mineral changes in incipient lesions *in vitro* and *in vivo* (17-20). When enamel demineralization occurs, minerals are replaced by water from saliva, which reduces light absorption. Thus, the intensity of the fluorescence decreases in such areas of the enamel, which appear as dark zones differing from sound structures (20).

Assessment of WSLs and deciding whether infiltration treatment would be efficient prior to the application is important. Varying clinical outcomes have been reported regarding the masking ability of this treatment, resulting in partial or unsuccessful camouflage of the lesions (21, 22). Data are lacking regarding the assessment of infiltration treatment efficacy in terms of lesion severity. Therefore, the aim of this study was to classify the WSLs identified after completion of orthodontic treatment by the lesion severity and to test the infiltration efficacy of these lesions by means of QLF. The null hypothesis tested was that efficacy of infiltration treatment would not differ between incipient or advanced WSLs.

## METHODS

### Study Design

The study protocol was approved by the ethics committee of Clinical Research of Medical School of Ege University (commission decision numbered 17-10/65). An informed consent form signed by the participant, and for those under age 18 years also signed by their parents, was obtained.

The participants were recruited consecutively for 6 months from patients being treated with fixed appliances at the department of orthodontics. The inclusion criteria were: patients of age 13 years or older, in good general health, with a treatment period with fixed appliances of at least 1 year at the debonding appointment, at least 1 WSL with no cavities present on the facial surface of the dentition before starting orthodontic treatment, and no prior WSL treatment utilized except tooth brushing with fluoridated toothpaste. The exclusion criteria were: patients with cavitated lesions, deciduous teeth, or WSLs that had been filled, restored, or had received therapy. If 1 exclusion criterion applied to 1 tooth, the subject was excluded from the trial.

No special attention was given to oral hygiene measures for subjects participating in this study immediately after debonding. At the start of fixed appliance treatment, the patients were advised to brush their teeth 3 times a day, were shown how to clean their mouth with the appliance in situ, and were given a leaflet with brushing instructions.



For every subject, the whole dentition was isolated with cotton rolls and air dried for 5 seconds. Subjects were diagnosed by a visual examination to determine the extent of demineralization, and the texture of the surface was gently evaluated with a periodontal probe. Carious white spot lesions appeared rough, opaque, and porous. Also, the presence and extent of lesions on the buccal surfaces of all teeth, except second and third molars, were assessed by means of QLF at the debonding visit.

Twenty eligible patients (12 boys, 8 girls; mean age, 15.6 years; n=57 teeth) who had recently finished orthodontic treatment were recruited by the second author (H.Ç).

At appliance removal, adhesive was removed with a carbide finishing bur, and complete removal was verified by air drying the teeth. All teeth were then polished with fluoride-free polishing paste using a rubber cup. No special measures were taken to remove plaque from the surfaces, apart from normal cleaning as part of the debonding procedure. After debonding, initial QLF imaging, infiltration treatment, and post-treatment QLF imaging were performed on the same day.

### QLF Imaging

All QLF images were captured by the same operator using an intraoral fluorescence camera (Inspektor Research Systems BV, Amsterdam, The Netherlands) in a dark room with no ambient light and processed on a personal computer using the image capturing software (QLF Patient version 2.0.0.48) that came with the system. Prior to each QLF imaging, the enamel surfaces were air dried for 5 seconds. To ensure that the images of the teeth surfaces were always captured from the same aspects, the video-repositioning utility of the QLF software was used with a minimum correlation rate of 0.90 (23). The WSL images were processed using the software, in which the lesions appeared as dark areas surrounded by bright green fluorescing sound tooth tissue (24). The fluorescence loss and lesion area were measured using the WSL tool of the software to determine the lesion severity. The total fluorescence loss (ΔF in percent), corresponding lesion area (area in $mm^2$), and the impact (ΔQ in $mm^2$ x %) were measured for each subject (Figure 1, 2).

### Infiltration Treatment

Following initial QLF recordings ($\Delta F_1$, $Area_1$, $\Delta Q_1$), lesions were treated by a single trained orthodontist with low-viscosity resin infiltrant (Icon, DMG, Hamburg, Germany) according to the manufacturer's instructions. The gingival soft tissues were protected with gingival barrier made of flowable composite resin. Fifteen percent HCl (Icon) was applied for 120 seconds on the lesion surface. Teeth were rinsed with water for 30 seconds and air dried. Then, they were treated with 99% ethanol (Icon Dry) for 30 seconds and air dried. In compliance with the manufacturer's instructions, the etching was repeated at this step if necessary.

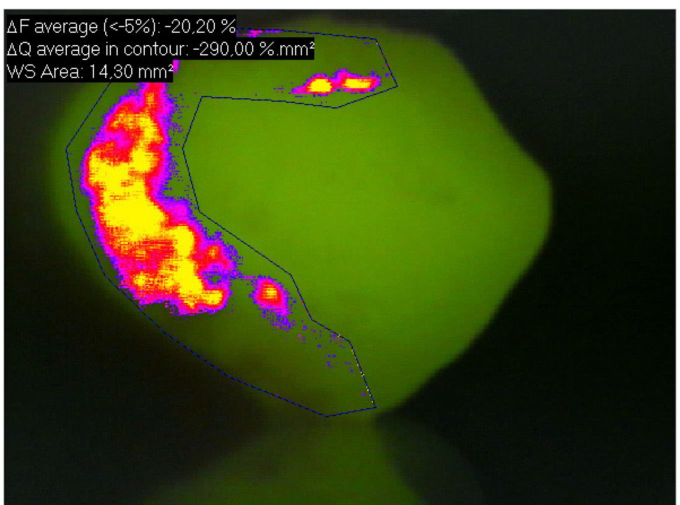


**Figure 1.** QLF image of the tooth 23 prior to resin infiltration. The black frame is the area of interest, where the software compares the fluorescence of sound and demineralized enamel

QLF: quantitative light-induced fluorescence

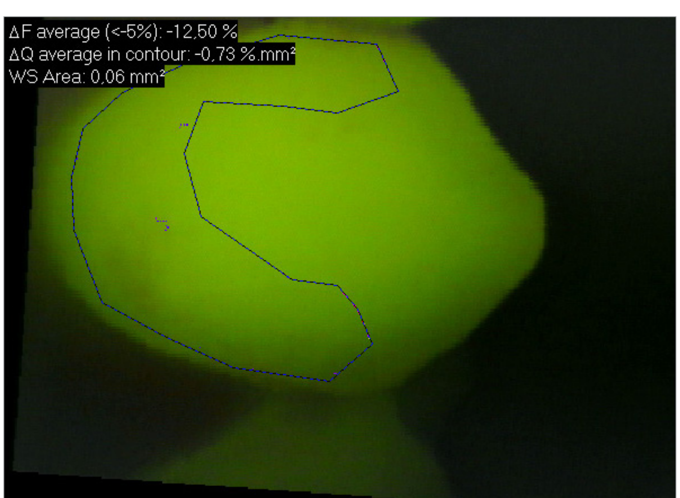


**Figure 2.** QLF image of the same tooth following resin infiltration

QLF: quantitative light-induced fluorescence



The need for additional etching was determined visually after the dry solution was used. One coat of infiltrant was applied with a microbrush, allowed to set for 180 seconds, and light-cured for 60 seconds. Then, a second layer was applied, allowed to set for 60 seconds, and light-cured for 40 seconds. The surfaces were polished with #4000 aluminum oxide abrasive paper. A second QLF imaging was performed immediately following the treatment ($\Delta F_2$, $Area_2$, $\Delta Q_2$).

### Statistical Analysis

All analyses were performed with the Statistical Package for Social Sciences version 21.0 (IBM Corp.; Armonk, NY, USA). Descriptive statistics, including the mean and standard deviation, were calculated for all groups. Kolmogorov–Smirnov and Shapiro–Wilk tests were used to test the normal distribution of the data. As the data were not normally distributed, the Wilcoxon test was applied to analyze possible differences between the groups for the same time points and the differences between the time points within each group. After this, the Mann-Whitney test was used separately for group and time combinations. The significance level was determined at a probability value of $p<0.05$.

Lesions were grouped according to the ranges of $\Delta F_1$, as either incipient ($-5<\Delta F_1<-12$, n=14) or advanced ($-12<\Delta F_1<-25$, n=43) (25). This provided over 90% power assuming that in 1 group (incipient) the standard deviation was 0.73, and in the other group (advanced) the standard deviation was 5.32. This was determined using a 2-group Satterthwaite t-test with a 0.05 2-sided significance level.

### Method Error Assessment

The accuracy of the QLF in recording the fluorescence loss and lesion area values was determined by repeating computer assessments of randomly selected lesions that were performed by the same operator (n=20). The intraclass correlation coefficient (ICC) was used to evaluate the intraexaminer agreement. The ICC of all measurements was 0.997, showing no significant difference between the measurements at 2 different time points.

## RESULTS

Fifty-seven clinically diagnosed WSLs (14 incipient, 43 advanced) were evaluated. The median fluorescence loss at debonding was −8.40% and −13.20% in the incipient and advanced groups, respectively. Median, interquartile range, minimum, and maximum values of incipient and advanced lesions before and after the infiltration procedure and groups presenting significant fluorescence changes are presented in Table 1.

Fluorescence of WSLs improved significantly following infiltration treatment in both groups ($p=0.001$, $p<0.001$). The median value for total lesion area per lesion was 3.44 $mm^2$ initially, which decreased to 0.18 $mm^2$ in the incipient group. In the advanced group, lesion area was 4.71 $mm^2$, which then decreased to 0.29 $mm^2$ following treatment. The median values for $\Delta Q_1$ at debonding were 30.75 and 57.50 in the incipient and advanced groups, respectively. In the incipient group, $\Delta Q_2$ was 1.24 following infiltration treatment whereas it was 1.86 for the advanced

**Table 1.** Median, interquartile range (IQR), minimum (Min), and maximum (Max) values of incipient and advanced lesions before and after infiltration procedure

| | Incipient (n=14) | | | | | Advanced (n=43) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Median | IQR | p | Min. | Max. | Median | IQR | p |
| ΔF1 (%) | −7.12 | −9.69 | −8.40 | −2.57 | 0.001 | −10.00 | −33.20 | −13.2 | −23.20 | <0.001 |
| ΔF2 (%) | −5.88 | −9.18 | −6.58 | −3.30 | | −5.56 | −15.60 | −7.51 | −10.04 | |
| Area1 (mm²) | 0.19 | 14.06 | 3.44 | 13.87 | 0.001 | 0.10 | 22.70 | 4.71 | 22.61 | <0.001 |
| Area2 (mm²) | 0.00 | 1.18 | 0.18 | 1.18 | | 0.00 | 6.70 | 0.29 | 6.70 | |
| ΔQ1 (mm² x %) | −1.60 | −133.00 | −30.75 | −131.40 | 0.001 | −1.86 | −336.00 | −57.50 | −334.14 | <0.001 |
| ΔQ2 (mm² x %) | −0.02 | −10.80 | −1.24 | −10.78 | | −0.01 | −88.20 | −1.86 | −88.19 | |

* Statistically significant at p≤0.05
p values indicate significant differences between two time points within the same lesion group

**Table 2.** Median, interquartile range (IQR), minimum (Min), and maximum (Max) value differences of incipient and advanced lesions before and after the infiltration procedure

| | Incipient | | | | Advanced | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Median | IQR | Min. | Max. | Median | IQR | p * |
| ΔF1-ΔF2 | −0.13 | −2.89 | −1.68 | −2.76 | −0.30 | −27.00 | −5.60 | −26.69 | <0.001 |
| Area1-Area2 | 0.17 | 13.37 | 3.34 | 13.20 | −0.01 | 19.34 | 2.67 | 19.36 | 0.690 |
| ΔQ1-ΔQ2 | −1.45 | −122.20 | −30.10 | −120.75 | −1.67 | −318.11 | −49.24 | −316.44 | 0.291 |

* Statistically significant at p≤0.05
p values indicate significant differences of the infiltration effect between the 2 lesion groups



group. When ΔF, lesion area, and ΔQ changes between the groups were compared, the decrease in ΔF was greater for advanced lesions (p<0.001) whereas the decrease in the lesion area (p=0.690) and ΔQ (p=0.291) was similar (Table 2).

## DISCUSSION

Assessment of low-viscosity resin infiltration efficacy in incipient and advanced WSLs was the main aim of this study. The results showed that fluorescence loss, lesion area, and impact decreased significantly in both incipient and advanced lesions. The amount of improvement in fluorescence loss was greater in advanced lesions but for the other 2 parameters the amount of improvement was similar in both incipient and advanced lesions. Therefore, the null hypothesis can be partially rejected.

The state of the cariogenic activity as the WSL is diagnosed determines the topographic characteristics of the lesion (13). The exterior surfaces of active WSLs are more porous and permeable whereas the surfaces of the passive WSLs are more intact and less permeable (11). This considerably affects the penetration of both the remineralization agents and the infiltration adhesive into the lesion body. Factors identifying the state of cariogenic activity are the presence of an uneven surface during probing, appearance of opacity after being air dried, dental plaque presence over the lesion surface, and gingival bleeding in the area adjacent to the lesion (26). Elapsed time between the detection of the lesion and the infiltration procedure should be minimized to prevent the surface from become more intact (14, 27). Paris et al. (13) suggested that in postorthodontic WSLs, the infiltration treatment should be done as soon as possible following bracket removal, fearing that the lesion at that time is active and would eventually lose its surface integrity. In this study, the infiltration procedure was applied during the appointment for bracket removal of the tooth with WSL, in order to standardize the effect as well as to improve it.

Repetition of the etching procedure has been advocated when severe and more opaque lesions are to be treated, assuming that the outer layer is less permeable. This need can be determined during the ethanol application step in cases in which the opacity of the lesion does not disappear (22). In the present study, the etching procedure was repeated up to 3 times only when necessary at this stage.

WSLs have been shown to decrease in size within 8 weeks following bracket removal if the etiological factors had been eliminated (28). Combinations of surface remineralization via saliva and other remineralization agents as well as toothbrush abrasion result in the gradual reduction of the affected tissue, thereby providing the natural regression of the lesion (29). It has been demonstrated that remineralization occurs mostly on the surface and the peripheries of the lesion, which improves the visual appearance by decreasing the opacity (6). The remaining lesions have been shown to have limited improvement, which might impair the esthetic appearance (22, 30). For this reason, arresting of such lesions has been advocated, in which the infiltrant would penetrate into the capillary structures of the lesion body offered by its low contact angle formed between the liquid (in this case the infiltrant resin) and high wettability potential with a significantly deeper penetration in the lesion body (13). These infiltrant features are rather important to ensure effectiveness (6, 11, 22, 27).

The masking ability of the infiltration stems from the light refractive index of the low-viscosity resin (1.475), which is similar to the refractive index of sound enamel (1.65). Thus, the opacity appears masked following a successful infiltration procedure. Because QLF utilizes the refraction of light from the surface, the fluorescence difference of the WSL as compared to adjacent sound enamel decreases (30). Although some aesthetic improvement is observed (27, 31), the lesion may not be camouflaged totally in severely advanced lesions. This may be due to the incomplete infiltration of the lesion body and the polymerization shrinkage (13). In the present study, fluorescence loss, lesion area, and impact (which represents a combination of fluorescence loss and lesion area), improved significantly for both incipient and advanced lesions. The amount of improvement regarding fluorescence loss was significantly higher for advanced lesions, whereas the reduction in the lesion area and impact were similar for both advanced and incipient lesions. Although both lesion groups were infiltrated almost completely, revealing very low lesion area values, corresponding fluorescence loss improvements were higher for advanced lesions, as one would expect. Unlike previous reports of partially infiltrated lesions (21, 22, 32), almost all lesion areas were reduced to a level where only a very small area of fluorescence loss could be detected. This might be due to the fact that immediate infiltration of active lesions was performed in this study. It might be speculated that the leftover detected area might be the center of the lesion body where the infiltration is least efficient.



The decision to remineralize or immediately infiltrate clinically diagnosed WSLs is a critical one. The patient's oral hygiene history during the treatment, his/her manual dexterity in tooth brushing, personal perception, and awareness level are possible determinants of this decision. Immediate infiltration of WSLs in patients with poor oral hygiene and low remineralization expectancy is advocated (27).

The uneven and limited number of lesions in study groups was one of the shortcomings of this study. Consecutive patients with WSLs in a 6-month timeframe were included, and it was not possible to equalize the number of lesions for each group. A larger scale study with long-term follow-up of the infiltrated lesions would add more depth to the present data.

## CONCLUSION

Within the limitations of this study, the following could be concluded:

- Low-viscosity resin infiltration improves fluorescence loss, lesion area, and impact in both incipient and advanced lesions.
- Immediate infiltration of clinically diagnosed WSLs can be the primary choice of treatment in orthodontic patients with poor oral hygiene and low remineralization expectancy.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of Clinical Research of Medical School of Ege University (commission decision numbered 17-10/65).

**Informed Consent:** Written informed consent was obtained from the patients who participated in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - E.Y.; Design - E.Y., R.A.; Supervision - E.Y.; Materials - H.Ç., E.Y., R.A.; Data Collection and/or Processing - H.Ç., E.Y., Y.L.S.; Analysis and/or Interpretation - Y.L.S.; Literature Search - Y.L.S.; Writing Manuscript - Y.L.S, E.Y.; Critical Review - Y.L.S., E.Y.

**Conflict of Interest:** The authors have no conflict of interest to declare.

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## REFERENCES

1. Summitt JB, Robbins JW, Hilton TJ, Schwartz RS. Fundamentals of Operative Dentistry: A Contemporary Approach. Quintessence Int 2006; 1: 2-4.
2. Boersma JG, van der Veen MH, Lagerweij MD, Bokhout B, Prahl-Andersen B. Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: influencing factors. Caries Res 2005; 39: 41-7. [CrossRef]
3. Featherstone JD. Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol 1999; 27: 31-40. [CrossRef]
4. Knösel M, Bojes M, Jung K, Ziebolz D. Increased susceptibility for white spot lesions by surplus orthodontic etching exceeding bracket base area. Am J Orthod Dentofacial Orthop 2012; 141: 574-82. [CrossRef]
5. Nyvad B, Machiulskiene V, Baelum V. Reliability of a new caries diagnostic system differentiating between active and inactive lesions. Caries Res 1999; 33: 252-60. [CrossRef]
6. Rocha Gomes Torres C, Borges AB, Torres LM, Gomes IS, de Oliveira RS. Effect of caries infiltration technique and fluoride therapy on the colour masking of white spot lesions. J Dent 2011; 39: 202-7. [CrossRef]
7. Selwitz RH, Ismail AI, Pitts NB. Dental caries. Lancet 2007; 369: 51-9. [CrossRef]
8. Cury JA, Tenuta LM. Enamel remineralization: controlling the caries disease or treating early caries lesions. Braz Oral Res 2009; 23: 23-30. [CrossRef]
9. Karlsson L, Lindgren L, Trollsas K, Angmar-Mansson B, Tranaeus S. Effect of supplementary amine fluoride gel in caries-active adolescents: a clinical QLF study. Acta Odontol Scand 2007; 65: 284-91. [CrossRef]
10. González-Cabezas C. The chemistry of caries: remineralization and demineralization events with direct clinical relevance. Dent Clin North Am 2010; 54: 469-78. [CrossRef]
11. Meyer-Lueckel H, Paris S. Progression of artificial enamel caries lesions after infiltration with experimental light curing resins. Caries Res 2008; 42: 117-24. [CrossRef]
12. Kielbassa AM, Muller J, Gernhardt CR. Closing the gap between oral hygiene and minimally invasive dentistry: a review on the resin infiltration technique of incipient [proximal] enamel lesions. Quintessence Int 2009; 40: 663-81.
13. Paris S, Meyer-Lueckel H, Cölfen H, Kielbassa AM. Resin infiltration of artificial enamel caries lesions with experimental light curing resins. Dent Mater J 2007; 26: 582-8. [CrossRef]
14. Al-Khateeb S, Forsberg CM, de Josselin de Jong E, Angmar- Mansson B. A longitudinal laser fluorescence study of white spot lesions in orthodontic patients. Am J Orthod Dentofacial Orthop 1998; 113: 595-602. [CrossRef]

15. Li J, Xie X, Wang Y, Yin W, Antoun JS, Farella M, et al. Long-term remineralizing effect of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) on early caries lesions in vivo: A systematic review. J Dent 2014; 42: 769-77. [CrossRef]
16. Al-Khateeb S, Exterkate RA, de Josselin de Jong E, Angmar-Månsson B, ten Cate JM. Light-induced fluorescence studies on dehydration of incipient enamel lesions. Caries Res 2002; 36: 25-30. [CrossRef]
17. Benson PE, Pender N, Higham SM. Quantifying enamel demineralization from teeth with orthodontic brackets-a comparison of two methods. Part 1: repeatability and agreement. Eur J Orthod 2003; 25: 149-58. [CrossRef]
18. Benson PE, Pender N, Higham SM. Quantifying enamel demineralization from teeth with orthodontic brackets-a comparison of two methods. Part 2: validity. Eur J Orthod. 2003; 25: 159-65. [CrossRef]
19. Pretty IA, Pender N, Edgar WM, Higham SM. The in vitro detection of early enamel de- and re-mineralization adjacent to bonded orthodontic cleats using quantitative light-induced fluorescence. Eur J Orthod 2003; 25: 217-23. [CrossRef]
20. Tranaeus S, Al-Khateeb S, Björkman S, Twetman S, Angmar-Månsson B. Application of quantitative light-induced fluorescence to monitor incipient lesions in caries-active children. A comparative study of remineralisation by fluoride varnish and professional cleaning. Eur J Oral Sci 2001; 109: 71-5. [CrossRef]
21. Hammad SM, El Banna M, El Zayat I, Mohsen MA. Effect of resin infiltration on white spot lesions after debonding orthodontic brackets. Am J Dent 2012; 25: 3-8.
22. Paris S, Meyer-Lueckel H. Masking of labial enamel white spot lesions by resin infiltration - A clinical report. Quintessence Int 2009; 40: 713-8.
23. Buchalla W, de Josselin de Jong E, Ando M, Eggertsson H, Lennon A, Stookey GK. Video-repositioning: increased repeatability for QLF caries monitoring method. J Dent Res 2001; 80: 115.
24. Josselin de Jong E, Sundström F, Westerling H, Tranaeus S, ten Bosch JJ, Angmar-Mansson B. A new method for in vivo quantification of changes in initial enamel caries with laser fluorescence. Caries Res 1995; 29: 2-7. [CrossRef]
25. Kim HE, Kwon HK, Kim BI. Recovery percentage of remineralization according to severity of early caries. Am J Dent 2013; 26: 132-6.
26. Ferreira MA, Mendes NS. Factors associated with active white enamel lesions. Int J Paediatr Dent 2005; 15: 327-34. [CrossRef]
27. Knösel M, Eckstein A, Helms HJ. Durability of esthetic improvement following Icon resin infiltration of multibracket-induced white spot lesions compared with no therapy over 6 months: a single-center, split-mouth, randomized clinical trial. Am J Orthod Dentofacial Orthop 2013; 144: 86-96. [CrossRef]
28. Kim S, Katchooi M, Bayiri B, Sarikaya M, Korpak AM, Huang GJ. Predicting improvement of postorthodontic white spot lesions. Am J Orthod Dentofacial Orthop 2016; 149: 625-33. [CrossRef]
29. Al-Khateeb S, Forsberg CM, de Josselin de Jong E, Angmar-Mansson B. A longitudinal laser fluorescence study of white spot lesions in orthodontic patients. Am J Orthod Dentofacial Orthop 1998; 113: 595-602. [CrossRef]
30. Mattousch TJH, van der Veen MH, Zentner A. Caries lesions after orthodontic treatment followed by quantitative light-induced fluorescence: a 2-year follow-up. Eur J Orthod 2007; 29: 294-8. [CrossRef]
31. Chen M, Li JZ, Zuo QL, Liu C, Jiang H, Du MQ. Accelerated aging effects on color, microhardness and microstructure of ICON resin infiltration. Eur Rev Med Pharmacol Sci 2019; 23: 7722-31.
32. Yuan H, Li J, Chen L, Cheng L, Cannon RD, Mei L. Esthetic comparison of white-spot lesion treatment modalities using spectrometry and fluorescence. Angle Orthod. 2014; 84: 343-9. [CrossRef]

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Original Article

# Nahoum Index in Brachyfacial Patients: A Pilot Study

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## ABSTRACT

**Objective:** Our aim is to test the Nahoum Index as a support in the cephalometric study of vertical dimension and therapeutic orientation in adult patients suffering from Class II malocclusion, deep bite, or short face syndrome.

**Methods:** Twenty-three patients with molar Class II and an overbite >4 mm were stratified into two groups: orthodontic (G2) and surgical orthodontic (G1). The ANB angle and Nahoum Index were calculated for cephalometric tracing pre- and post-treatment. The difference between the ANB and Nahoum Index values were analyzed using the Statistical Package for the Social Sciences software.

**Results:** In G1, the Nahoum Index decreased from 0.954 to 0.797, and the ANB angle decreased from 5.2° to 3.2°. In G2, the Nahoum Index decreased from 0.825 to 0.817, and the ANB angle decreased from 4.4° to 4°.

**Conclusion:** In G1, the difference between before and after treatment was significant for the Nahoum Index only. The difference between before and after values was not significant in the G2 group. It is possible to indicate the Nahoum Index of 0.934 as the limit value in case of which a patient may be treated with orthodontics only. This limit is the opposite of the limit proposed by Nahoum for vertical excess cases and respect the same interval. Therefore, we can consider the range 0.81-0.934 to indicate borderline patients, and >0.934 to indicate surgical patients. If the ratio is close to the normal value as 0.81, the treatment will be orthodontic; if it is further increased, the treatment will be surgical.

**Keywords:** Brachyfacial, cephalometry, deep bite, index, malocclusion, syndrome

## INTRODUCTION

The study of the brachyfacial typology, characterized by a defect of the anterior vertical dimension with respect to the transversal dimension, is very interesting and complex. This defect can be due to a dentoalveolar and/or skeletal anomaly, and it often involves all the connected dentofacial structures. The reduction of the vertical dimension can also reach the characteristics of a syndrome, called short face syndrome (SFS) (1-3). Cephalometric analysis is very important in defining this facial typology to decide if the clinical characteristics can be treated with an orthodontic or surgical orthodontic treatment. The Nahoum index is used to determine the amount of facial vertical disorder in the appraisal of the open bite; the Index is indicated to identify which treatment is better: orthodontic or surgical orthodontic (4). Nahoum established the value of 0.81 as the normal ratio, a harmonious relationship between the upper and lower facial portions. When the value is between 0.686 and 0.81, the patient is defined as borderline. If the ratio is <0.686, the case must be treated with maxillofacial surgery. The Nahoum Index is currently used in the pre-surgical Orthodontic Unit of the orthodontics COU in Sapienza University of Rome in the cephalometric analysis (5).

Although the Nahoum Index has been created by the authors as a support to cephalometric diagnosis and therapeutic orientation in open bites, and in any case of vertical excess of the lower third face, it could be also used in the diagnosis of dentofacial disorders when a deficit in the vertical dimension of the lower third is highlighted (6).

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Our aim was to test the Nahoum Index as a tool in the cephalometric study of the vertical dimension and therapeutic orientation in patients suffering from deep bite or SFS at the end of growth. A statistical analysis was performed to explain the clinical value of the Index in these patients and, as a secondary aim was, to suggest the most appropriate therapeutic approach. A retrospective study was designed to compare the values before and after the treatment of ANB angle and of the Nahoum Index in a group of patients affected by Class II malocclusion, who underwent orthodontic-surgical correction of the sagittal and vertical discrepancy; the results were compared with a control group of patients treated with orthodontics only.

## METHODS

The study was approved by the Department of Oral and Maxillo-Facial Sciences and by the Ethical Board of the Umberto I General Hospital of the Sapienza University of Rome (protocol number 4663).

Among all the patients who were referred to our clinic, we selected a sample of adult patients consecutively treated and who completed the therapy, according to the inclusion and exclusion criteria. The inclusion criteria involved patients with the CS6 stage of cervical maturation, who had suffered from Class II malocclusion and were clinically classified on the basis of the occlusal molar relationship, and also had SFS face and/or deep bite (7). All the patients selected also had to have complete documentation, including clinical examination, photographic and, radiographic records, and cast models, at pre and post treatment. The exclusion criteria involved patients affected by cranio facial deformities or syndromes, patients atment with incomplete documentation, and patients who did not complete the therapy. For the inclusion in the study, we selected patients having Class II molar relationship and with an overbite more than 4 mm. The selected group of 23 subjects consisted of 9 men and 14 women, aged between 20-37 years. The patients were stratified into two groups according to the therapy performed. The first group consisted of patients who underwent orthodontic-surgical treatment (G1, 10 subjects); the second group consisted of patients treated only with orthodontics, and it was used as the control group (G2, 13 subjects) (Table 1. a, b). Among the patients in orthodontic-surgical group, 2 BSSO, 3 BSSO and genioplasty, 3 Le Fort I osteotomy and BSSO, and 2 Le Fort I, BSSO and genioplasty procedures were performed.

**Table 1a.** Patients treated with surgical orthodontic treatment involved in the study (G1), stratified by age and sex

| Patient | Sex | Age |
|---|---|---|
| 1 | m | 22 |
| 2 | f | 34 |
| 3 | f | 24 |
| 4 | m | 36 |
| 5 | m | 29 |
| 6 | m | 31 |
| 7 | f | 37 |
| 8 | f | 20 |
| 9 | f | 21 |
| 10 | m | 24 |

**Table 1b.** Patients treated with orthodontics involved in the study (G2), stratified by age and sex

| Patient | Sex | Age |
|---|---|---|
| 1 | f | 24 |
| 2 | f | 29 |
| 3 | f | 35 |
| 4 | f | 32 |
| 5 | f | 21 |
| 6 | m | 34 |
| 7 | m | 26 |
| 8 | f | 39 |
| 9 | m | 28 |
| 10 | f | 35 |
| 11 | m | 31 |
| 12 | f | 26 |
| 13 | f | 23 |

A retrospective analysis was then performed to measure the latero-lateral cephalometric tracing of each patient in both groups, at the beginning and at the end of therapy, and to identify the pattern of ANB angle, and the Nahoum Index. The Nahoum Index is the ratio between the upper anterior facial height (N-ANS, expressed in mm) and the lower anterior facial height (ANS–Me, expressed in mm). To test the data reliability, another Investigator repeated the measurements again in random order after 1 month, and the method error was calculated using Dahlberg's test.

### Statistical Analysis

For each group, we performed descriptive statistical analysis with calculation of the mean and standard deviation (SD). To highlight the characteristics of the two groups, the pre- and post-treatment values between the groups were evaluated with a *t*-test for independent samples. The null hypothesis to test if there was any significant difference between the groups, before the therapy, and that the Nahoum Index is useful to suggest the most appropriate therapeutic approach.

The differences between the values before and after treatment within both groups were tested using the analysis of variance, the F test, and the *t*-test for paired data. The significance level was set at 0.05.

The purpose of the statistical analysis was to verify possible differences between the two groups before the treatment, compare the before and after treatment results, and compare the two groups after treatment to obtain the clinical significance of the Nahoum Index in brachyfacial patients. The parameters were analyzed using the Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA).

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## RESULTS

The results of the Dahlberg test were 0.4° for the measure of ANB and 0.08 for the Nahoum Index, indicating a good inter-examiner reliability for both measures. Especially for the Nahoum Index, these results are important because the Index is a pure number without units of measurements, and it depends on the measure of two linear distances.

**Table 2.** Parameters of the orthodontic-surgical group (G1)

| | Nahoum Index | | ANB Angle | |
|---|---|---|---|---|
| Patient | Pre-treatment | Post-treatment | Pre-treatment | Post-treatment |
| 1 | 0.97 | 0.69 | 6 | 7 |
| 2 | 1.02 | 0.81 | 4 | 4 |
| 3 | 0.96 | 0.8 | 8 | 3 |
| 4 | 1.01 | 0.88 | 1 | 1 |
| 5 | 0.95 | 0.8 | 6 | 1 |
| 6 | 0.94 | 0.7 | 3 | 1 |
| 7 | 0.98 | 0.93 | 2 | 1 |
| 8 | 0.93 | 0.84 | 7 | 5 |
| 9 | 0.89 | 0.78 | 7 | 5 |
| 10 | 0.89 | 0.74 | 8 | 4 |
| Mean (SD) | 0.954 (0.044) | 0.797 (0.075) | 5.2 (2.53) | 3.2 (2.15) |

**Table 3.** Parameters of the orthodontic group (G2)

| | Nahoum Index | | ANB Angle | |
|---|---|---|---|---|
| Patient | Pre-treatment | Post-treatment | Pre-treatment | Post-treatment |
| 1 | 0.7 | 0.73 | 6 | 6 |
| 2 | 0.79 | 0.78 | 2 | 2 |
| 3 | 0.94 | 0.9 | 3 | 4 |
| 4 | 0.82 | 0.81 | 2 | 2 |
| 5 | 0.71 | 0.73 | 1 | 1 |
| 6 | 0.82 | 0.81 | 5 | 3 |
| 7 | 0.91 | 0.88 | 2 | 2 |
| 8 | 0.84 | 0.81 | 5 | 6 |
| 9 | 0.8 | 0.78 | 3 | 0 |
| 10 | 0.74 | 0.75 | 9 | 8 |
| 11 | 0.99 | 0.98 | 5 | 5 |
| 12 | 0.84 | 0.86 | 6 | 6 |
| 13 | 0.83 | 0.8 | 8 | 7 |
| Mean (SD) | 0.825 (0.085) | 0.817 (0.072) | 4.38 (2.46) | 4 (2.51) |

**Table 4.** Results of T-test for the comparison of values before and after treatment

| | G1 | G2 |
|---|---|---|
| Nahoum Index | p<0.001 | 0.786 |
| ANB | 0.0728 | 0.6975 |

**Table 5.** T-test for comparison of values between groups before and after treatment

| | Before | After |
|---|---|---|
| Nahoum | p<0.001 | 0.5256 |
| ANB | 0.4457 | 0.4305 |

For both groups, Table 2 and 3 report the results of the parameters studied. In the surgical orthodontic group, the Nahoum Index before treatment was higher than the normal value (0.81), with a mean of 0.954 (SD, 0.045); after the surgical orthodontic treatment, with the recovery of a physiological vertical dimension, the mean value was 0.797 (SD, 0.075). The mean value of the ANB angle was found 5.2°(SD, 2.53) before treatment, and 3.2° (SD,2.15) at the end of treatment.

In the orthodontic group (G2), the mean Nahoum Index before treatment was 0.825 (SD, 0.084). At the end of the treatment, the mean value was 0.817 (SD, 0.072). The average value of the ANB angle before the treatment was 4.4° (SD, 2.47), and at the end, it was 4° (SD, 2.52). In the G1 group, the difference between before and after treatment was significant for the Nahoum Index only. The differences between the before and after values were not significant in the G2 group (Table 4, 5).

To compare the two groups, a *t*-test for independent data was performed to compare the intragroup values before as well as after treatment. Before treatment, the mean Nahoum Index was statistically different between groups. After the treatment, the two groups did not have significant differences regarding the two parameters analyzed (Table 4, 5).

## DISCUSSION

The typical brachyfacial patient may not only be affected by a dentoalveolar disease, but all the structures of the stomatognathic system were involved, defining what is more properly called short face syndrome (8, 9). These patients are usually characterized by a skeletal decrease of the lower third of the face with the mandible having a closed gonial angle and anticlockwise rotation of the mandibular plane, which tends to be parallel to the Frankfort horizontal plane (10, 11). The maxilla may appear normal or hypoplastic, with a reduced dentoalveolar height, or even with vertical overdevelopment of the incisal portion and inversion of the upper occlusal compensation curve, and the palatal plane is rotated clockwise. Patients with SFS usually suffer from inadequate sagittal mandibular development, thus resulting in a skeletal Class II malocclusion. Some patients show palatal inclination of the upper incisors (Class II Division 2), giving a typical trapezoidal shape of the upper arch and linguo-version of lower incisors, other patients show over-inclination of the upper incisors (Class II Division 1). Both types of malocclusion can lead to an occlusal contact between lower incisors and palatal mucosa. These structural abnormalities affect the adaptation of the soft tissues to the skeleton, leading to: the rolling up of the lower lip with a deepening of the lip-dental groove, which gives the patient the typical "sullen" look; a prominent chin; Furthermore, the labial tension may determine an increase in overbite, with severe crowding of lower incisors and serious deepening of the curve of Spee. TMJ disorders may be present for the reduction of the physiological spaces of the temporomandibular joint and for the anterior disc displacement (12, 13).

Orthodontic treatment of a Class II malocclusion with deep bite is based on the opening of the bite and the flattening of the curve of Spee, which normally occurs with an extrusion of the posterior sectors to determine a clockwise rotation of the mandible (1). As a result, the posterior facial height increases, but the existing Class II relationship worsens. Moreover, the masticatory muscles, well developed in this type of patients, tend to counteract the extrusion obtained orthodontically. In cases where a short face skeletal dysgnathia is present, in addition to dental malocclusion, an increase of the height of the lower facial third is one of the most important purposes: the conventional orthodontic treatment corrects the malocclusion but is usually ineffective in changing facial proportions in patients with SFS; therefore, adult patients with SFS need a combined surgical orthodontic treatment for the complete resolution of the disease as described by Turley (14).

In surgical orthodontic cases, the opening of the bite is the first orthodontic purpose, which allows to obtain the correct axial positioning of the incisors in relation to their skeletal bases, to properly assess the real crowding of the arches, to reveal the real extent of the skeletal discrepancy, usually masked by the retroclination of upper and lower incisors and to coordinate the transversal diameters (1, 15, 16). After the intrusion of the incisors, leveling is completed with the correction of the curve of Spee. Once the leveling of the arches was achieved, it is possible to assess the need for extractions and finally the pre-surgical coordination of the arches.

From the above, it is clear the importance of assessing if a "short" vertical discrepancy is suitable to be corrected with orthodontics or orthognathic surgery: Nahoum, with its Index, set the parameters with respect to open bites; in this study an evaluation of this Index is tested for the application in patients with deep bite.

In this retrospective study, the average value of the Nahoum Index at pretreatment inthe group G2 appeared to be very close to normal value, indicating a proper vertical relationship. These patients from a cephalometric point of view did not show a vertical skeletal disorder and were properly treated with orthodontics. At the end of treatment, the normal value of the Index did not change because the orthodontic treatment was limited to the correction of the dentoalveolar alteration.

In this group, the average ANB angle (4.4°) confirmed the clinical diagnosis of skeletal Class II; after the treatment, the average value slightly decreased (equal to 4°), and this decrease was not statistically significant.

In Group G1, the average Nahoum Index before therapy had values far from the normal value, due to the vertical deficiency of the lower facial third. In these patients, ANB was increased, being equal to 5.2°; these patients also had a greater sagittal involvement than the other group, as well as a vertical skeletal disorder, so the complexity of the malocclusion required a combined surgical orthodontic intervention.

The average value obtained at the end of the orthognathic treatment showed how the recovery of a correct three-dimensional skeletal situation may also restore the vertical dimension, giving a ratio between the medium and lower facial third very close to the normal value proposed by Nahoum; this ratio indeed was slightly lower, probably because of a surgical vertical overcorrection, which is desirable in this kind of patients. The mean ANB angle after surgical correction (ANB, 3.2°) returned within normal ranges.

In disorders with deficiency of the lower facial third, we expect that the Nahoum Index will always be increased due to the decrease of the ANS–Me distance. If we see the differences between groups, the only parameter statistically different before therapy is the Nahoum Index. After therapy, there were no differences between the groups regarding both parameters.

Although this Index alone cannot provide precise indications of the best therapeutic approach in patients with deficit of lower facial third, it is possible to indicate the value of 0.934 as the limit value within which a patient may be treated with orthodontics only. This limit is the opposite of the limit proposed by Nahoum (<0.686) for cases with vertical excess, and it respects the same interval.



Therefore, we can consider the values between 0.934 and 0.81 as borderline cases and values >0.934 indicate surgical correction of the vertical defect. Our sample of surgical patients in fact exceeded this limit, having as the mean Index 0.954. Instead, the mean value of the patients treated with orthodontics is 0.825, very close to the normal value of 0.81.

It is obvious that the choice of the best treatment cannot be established only on the basis of vertical cephalometric parameters, but it must always be related to the sagittal and transversal characteristics of the patient. The choice of therapy, orthodontic or surgical orthodontic, will depend on how the vertical changes are related to concurrent sagittal and transversal disorders that affect the complexity of malocclusion. Further investigations conducted on a larger number of patients could improve the statistical significance of the study.

## CONCLUSION

The features of the brachyfacial morphotype affect the therapeutic choice, and the results could be obtained with the therapy. A cephalometric instrument that discriminates the dentoalveolar vertical discrepancy from the skeletal one could be useful.

The Nahoum Index can be, even in brachyfacial subjects, of great help in determining the most suitable treatment. If this ratio is close to the normal values, the treatment will be orthodontic; if the ratio is further increased, the approach will be surgical.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Department of Oral and Maxillo-Facial Sciences and by the Ethical Board of the Umberto I General Hospital of the "Sapienza" University of Rome (protocol number 4663).

**Informed Consent:** Informed consent wasn't necessary for to the retrospective nature of this cohort study.

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## REFERENCES

1. Silvestri A, Macrì V, Grenga V. Problematiche ortodontiche nel trattamento delle malformazioni dento-scheletriche di Classe II divisione 2. Mondo Ortodontico 1987; 5: 51-63.
2. Watted N, Wieber M, Teuscher T, Bill JS, Reuther J. Surgical lengthening of the lower face in patients with class II deformities and skeletal deep bite--"short face syndrome" controlled clinical study on the "Würzburger Konzept". Mund Kiefer Gesichtschir 2002; 6: 415-20. [CrossRef]
3. Watted N, Witt E, Bill JS. A therapeutic concept for the combined orthodontic surgical correction of angle Class II deformities with short-face syndrome: Surgical lengthening of the lower face. Clin Orthod Res 2000; 3: 78-93. [CrossRef]
4. Henry I, Nahoum H. Anterior open-bite: a cephalometric analysis and suggested treatment procedures. Am J Orthod 1975; 67: 513-21. [CrossRef]
5. Silvestri A, Ferraris L, Vernucci R.A. Analisi cefalometrica del paziente in crescita e adulto. Mondo Ortodontico 2004; 3: 175-95.
6. Nahoum HI. Vertical proportions: a guide for prognosis and treatment in anterior open-bite. Am J Orthod 1977; 72: 128-46. [CrossRef]
7. Franchi L, Baccetti T, McNamara JA Jr. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthop 2000; 118: 335-40. [CrossRef]
8. Opdebeeck H, Bell WH. The short face syndrome. Am J Orthod 1978; 73: 499-511. [CrossRef]
9. Freihofer HP. Surgical treatment of the short face syndrome. J Oral Surg 1981; 39: 907-11.
10. Bhateja NK. Deep Bite Malocclusion: Exploration of the Skeletal and Dental Factors. J Ayub Med Coll Abbottabad 2016; 28: 449-54.
11. Karlsen AT. Craniofacial characteristics in children with Angle Class II div. 2 malocclusion combined with extreme deep bite. Angle Orthod 1994; 64: 123-30.
12. Zuaiter S, Robin O, Gebeile-Chauty S, Raberin M. Does dental class II division 2 predispose to temporomandibular disorders? Orthod Fr 2013; 84: 277-85.
13. Sonnesen L, Svensson P. Temporomandibular disorders and psychological status in adult patients with a deep bite. Eur J Orthod 2008; 30: 621-9. [CrossRef]
14. Turley PK. Orthodontic management of the short face patient. Semin Orthod 1996; 2: 138-53. [CrossRef]
15. Jacobs JD, Sinclair PM. Principles of orthodontic mechanics in orthognatic surgery case. Am J Orthod 1983; 84: 399-407. [CrossRef]
16. Jacobs JD, Bell WH, Williams C, Kennedy J. Control of the transverse dimension with surgery and orthodontics. Am J Orthod 1980; 77: 284-306. [CrossRef]

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Original Article

# Evaluation of Dental Age in Individuals of Different Ages with Unilateral Cleft Lip and Palate

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## ABSTRACT

**Objective:** This study aimed to evaluate the dental age of unilateral cleft lip and palate (UCLP) patients aged 7–12 and 12–16 years using Demirjian's method and to compare these results with a control group.

**Methods:** We evaluated the panoramic radiographs of 54 individuals with UCLP and 54 age- and gender-matched individuals without UCLP (control). The UCLP and control groups were divided into two groups: 7–12 and 12–16 years of age. Their dental ages were determined using Demirjian's method. Dental ages of the cleft side and noncleft side were assessed separately and were also compared with those of the control group to assess potential asymmetric dental developments in the UCLP group.

**Results:** The chronological age was lower than the dental ages on both right and left sides in the control group ($p<0.01$). When age groups were evaluated separately, it was found that the chronological age was lower than the dental age in 7–12 year old individuals in the UCLP group ($p<0.05$), whereas it was less than the left and right dental ages in 7–12 ($p<0.01$) and 12–16 year old individuals ($p<0.05$) in the control group.

**Conclusion:** We detected no differences in dental age between UCLP patients and healthy controls, and lack of asymmetrical dental development in the mandibular teeth of either group. However, based on assessments performed using Demirjian's method, subjects' dental and chronological ages were incompatible.

**Keywords:** Unilateral cleft lip and palate, dental age, tooth development

## INTRODUCTION

Cleft lip and palate (CLP) is the most common congenital anomaly of the craniofacial region. Individuals with orofacial clefts often exhibit dental anomalies that originate from the development of dentition (1, 2).

Follow-up and treatment of the dentofacial region in CLP patients require multidisciplinary treatment planning starting from the early stages of development (3). Therefore, dental age determination is important for establishing the course of treatment in these patients. For orthodontists, determining the dental development is important for planning the treatment of various malocclusions related to maxillofacial growth; the ability to accurately estimate the phases and stages of tooth development can influence the course of pedodontic treatment. In general, dental age can be determined based on an assessment of tooth eruption or tooth formation (4-6). However, assessing tooth eruption is not a reliable way of determining dental age because it is affected by local factors such as the primary dentition.

The most commonly used method to estimate dental age is the system introduced by Demirjian et al. (4). Using panoramic radiographs from 2928 French–Canadian patients (1446 males and 1482 females), eight

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stages (A to H) were established for each tooth on the mandibular left side according to tooth development criteria, such as dentine clustering and pulpal wall formation. Each stage received a score, and the total scores were matched with the corresponding dental ages in a table in chronological order. According to the researchers, this system is useful for dental patients of age 3–17 years. The rationale for using only the left mandibular teeth in this system was attributed to the exact correspondence between the right and the left sides. Although this method is very easy to apply, it has generated conflicting opinions because of the potential for different outcomes in different ethnicities or even in different areas within the same geographical region (7-11).

During embryological development, tooth germ formation is closely related to CLP in terms of timing and anatomical position (12-14). Many previous studies have reported various anomalies in individuals with CLP such as delayed dental maturation, dental age retardation as opposed to individuals without cleft, and asymmetric dental development (15-19). A study on Brazilian children conducted by Topolski et al. (20) revealed a distinct incompatibility between dental and chronological ages in both the CLP and control groups, whereas no significant retardation in dental age was observed in CLP compared with the controls. In southern China, Lai et al. (21) reported that the incidence of asymmetric and delayed dental development was higher in children with CLP than in healthy individuals. They also demonstrated that delay in dental development may be greater in children with CLP as the number of missing teeth increases.



However, few studies have attempted to evaluate different age groups. In one study that investigated the correlation between chronological age and skeletal maturation of individuals with CLP, the authors underlined that skeletal development was found to be retarded in the early years (7-11 years) but approached that of the healthy individuals later in life (14-18 years) (22). These results raise the question of whether there is dental age deficiency between different age groups in Turkish individuals with UCLP.

Scientific determination of age plays a critical role in the diagnosis and treatment planning processes; hence, it is very essential in forensic medicine, pediatric endocrinology, and clinical dentistry (8). Recent studies have drawn attention to the relationship between CLP and developmental problems in later life (22). UCLP patients were also reported to be commonly associated with delayed dental development (18). Orthodontic and pedodontic treatments for children with CLP usually start at the early stages of childhood. Therefore, it is crucial to know the estimated eruption time and the time coinciding with teeth development. To the best of our knowledge, there is no study that evaluates dental age in Turkish UCLP patients. In light of this information, the present study aimed to estimate the dental age of unilateral CLP (UCLP) patients in two different age groups (7-12 and 12-16 years) using the Demirjian's method and to compare our findings with a control group of healthy individuals.

## METHODS

### Subjects

The study was conducted using panoramic radiographs obtained for routine dentistry procedures (e.g., tooth extraction, filling and/or root canal, orthodontic treatment) from individuals with UCLP admitted to the Center for Oral and Maxillofacial Medicine of Medipol Mega Hospitals, the İstanbul Medipol University School of Dentistry, and the Ankara University School of Dentistry for treatment. The study was approved by the İstanbul Medipol University School of Dentistry ethics committee (approval number: 543)

Inclusion criteria for the study were as follows:

1. Subjects did not exhibit any other congenital anomalies or syndromes in the craniofacial region other than unilateral UCLP;
2. Subjects had not undergone orthodontic treatment/orthognathic surgery prior to the acquisition of panoramic radiographs;
3. Subjects did not have any congenitally missing mandibular teeth or extracted mandibular teeth other than the third molars on the right and left sides.

We used GPower 3.1.0 software package (Universität Düsseldorf, Düsseldorf, Germany) to determine the number of individuals included in the study, and we further performed a power analysis. Based on a previous study, an expected effect size of r=0.5 was used in the power calculation (18). Sample size calculation was based on the ability to detect significant differences in dental age at $\alpha$=0.05 error probability (critical t: 1.66023; noncentrality parameter $\delta$: 2.52487). According to power analysis, a sample size of 51 patients for each group would allow for a power >80 % (actual power: 0.8058986) with an allocation ratio (N2/N1)=1. Therefore, a total of 108 panoramic radiographs were analyzed, 54 from UCLP patients (37 males, 17 females; mean age 12.12±2.13 years) and 54 from patients without CLP (37 males, 17 females; mean age, 12.13±2.13 years). The CLP patients included in the study were age- and sex- matched with the individuals without CLP, with a maximum chronological age difference of 2 months for each pair. The distribution of cleft sides in individuals with UCLP by gender is shown in Table 1.

The UCLP and control groups were divided into two chronological subgroups: 7-12 and 12-16 years of age. We distinguished the two groups based on the fact that permanent dentition is generally completed at 12 years of age. Because panoramic radiographs are not routinely taken for individuals under seven years of age, we accepted this lower age limit for this study. Patients older than 16 years of age were not included in the study because the Demirjian's method accepts that dental development is already completed in girls by that age.

### Assessment of Dental Age

To use Demirjian's method to determine the dental age of patients participating in the study, the patients' chronological ages were first calculated in years and months. All assessments were performed by two researchers who were blinded to the patients' clinical condition. The maxilla was excluded from the radiographs acquired to conceal the cleft side, facilitating objectivity in measurements.

Unlike Demirjian's method, the present study evaluated the teeth on both sides instead of only focusing on the left one. This allowed us to establish differences in the dental age between the CLP and healthy patients, and consequently determine whether patients exhibited mandibular asymmetric dental development or not. In addition to determining dental age in individuals with CLP, we compared the right and left sides in healthy individuals. Demirjian et al. (4) suggested the exact agreement between the left and right sides as the reason for using solely mandibular left-hand teeth for determining tooth age. Accordingly, we used the left mandibular teeth to compare CLP individuals with the control group. In addition, we compared the left side of the control group with the cleft side and the noncleft side of the CLP patients.

**Table 1.** Distribution of the cleft side by age and sex in individuals with unilateral cleft lip and palate

| | Age | Gender | Right | Left |
|---|---|---|---|---|
| UCLP | 7-12 | Male | 4 | 18 |
| | | Female | 3 | 4 |
| | 12-16 | Male | 4 | 11 |
| | | Female | 4 | 6 |
| | Total | | 15 | 39 |

### Statistical Analysis

The data obtained in this study were analyzed using The Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA). Intraclass correlation coefficient (ICC) was calculated to assess the agreement between the two observers' measurements. After performing normality tests on the data obtained, we used the Mann-Whitney U test for intergroup comparisons and the Wilcoxon signed rank test for intragroup comparisons.

## RESULTS

For interobserver reliability, ICC was calculated as 0.90 and reliability was found to be high.

No significant difference was detected between chronological and dental ages on the cleft and noncleft sides in the UCLP group. However, chronological age was found to be lower than dental age on both the left and right sides in the control group ($p<0.01$, Table 2).

No significant difference was found between the UCLP and control groups in terms of chronological age or between dental age (cleft and noncleft sides) in the UCLP group and left-side dental age in the control group (Table 3).

When age groups were evaluated separately, we found that chronological age was lower than dental age (cleft side and noncleft side) in the UCLP group aged 7–12 years ($p<0.05$), whereas chronological age was lower than the left and right dental ages in the control group aged 7-12 ($p<0.01$) and 12–16 years ($p<0.05$) (Table 4).



**Table 2.** Intragroup comparison of chronological and dental ages in the unilateral cleft lip and palate and control groups

| | | n=54 | | | Kruskall-Wallis H | | |
|---|---|---|---|---|---|---|---|
| | | Mean±SD | Min. | Max. | H | p | |
| UCLP | Chronological Age | 12.12±2.13 | 7.83 | 16.08 | 2.3 | 0.309 | - |
| | Dental Age (cleft side) | 12.55±2.17 | 7.60 | 16.00 | | | |
| | Dental Age (noncleft side) | 12.64±2.15 | 7.80 | 16.00 | | | |
| Control | Chronological Age | 12.13±2.13 | 8.00 | 16.08 | 9.3 | 0.009** | 1-2<br>1-3 |
| | Dental Age (right) | 13.16±2.38 | 8.20 | 16.00 | | | |
| | Dental Age (left) | 13.19±2.40 | 8.20 | 16.00 | | | |

Min: minimum; Max: maximum; SD: standard deviation (Kruskal-Wallis H test; **p<0.01)

**Table 3.** Comparison of chronological age and dental age in unilateral cleft lip and palate and control groups

| | | n=54 | | | Mann-Whitney U | |
|---|---|---|---|---|---|---|
| | | Mean±SD | Min. | Max. | z | p |
| Chronological Age | UCLP | 12.12±2.13 | 7.83 | 16.08 | –0.06 | 0.951 |
| | Control | 12.13±2.13 | 8.00 | 16.08 | | |
| Dental Age | UCLP (cleft side) | 12.55±2.17 | 7.60 | 16.00 | –1.54 | 0.123 |
| | Control (left) | 13.19±2.40 | 8.20 | 16.00 | | |
| | UCLP (noncleft side) | 12.64±2.15 | 7.80 | 16.00 | –1.48 | 0.138 |
| | Control (left) | 13.19±2.40 | 8.20 | 16.00 | | |

Min: minimum; Max: maximum; SD: standard deviation (Mann-Whitney U Test)

**Table 4.** Intragroup comparison of chronological and dental ages for the 7-12 and 12-16 year age subgroups in the unilateral cleft lip and palate and control groups

| | | | n | Mean±SD | Min. | Max. | Kruskall-Wallis H | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | H | p | |
| UCLP | 7-12 | Chronological Age | 29 | 10.44±1.02 | 7.83 | 11.83 | 6.9 | 0.031* | 1-2<br>1-3 |
| | | Dental Age (cleft side) | 29 | 11.23±1.77 | 7.60 | 14.60 | | | |
| | | Dental Age (noncleft side) | 29 | 11.26±1.72 | 7.80 | 14.60 | | | |
| | 12-16 | Chronological Age | 25 | 14.06±1.22 | 12.00 | 16.08 | 0.246 | 0.884 | - |
| | | Dental Age (cleft side) | 25 | 14.08±1.50 | 10.80 | 16.00 | | | |
| | | Dental Age (noncleft side) | 25 | 14.24±1.33 | 11.60 | 16.00 | | | |
| Control | 7-12 | Chronological Age | 29 | 10.46±1.03 | 8.00 | 11.92 | 12.03 | 0.002** | 1-2<br>1-3 |
| | | Dental Age (right) | 29 | 11.74±2.04 | 8.20 | 15.20 | | | |
| | | Dental Age (left) | 29 | 11.79±2.16 | 8.20 | 15.70 | | | |
| | 12-16 | Chronological Age | 25 | 14.06±1.23 | 12.00 | 16.08 | 6.7 | 0.033* | 1-2<br>1-3 |
| | | Dental Age (right) | 25 | 14.82±1.53 | 11.60 | 16.00 | | | |
| | | Dental Age (left) | 25 | 14.81±1.48 | 11.60 | 16.00 | | | |

Min: minimum; Max: maximum; SD: standard deviation (Kruskal-Wallis H test; **p<0.01)



**Table 5.** Sex-based comparison of chronological age and dental age between the unilateral cleft lip and palate and control groups in individuals aged 7-12 and 12-16 years

| | | | | n | Mean±SD | Min. | Max. | Mann Whitney U | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | z | p |
| UCLP | 7-12 | Chronological Age | M | 22 | 10.58 ±0.89 | 7.83 | 11.83 | −0.867 | 0.386 |
| | | | F | 7 | 10.01±1.33 | 8.33 | 11.58 | | |
| | | Dental Age (cleft side) | M | 22 | 11.46±1.52 | 8.10 | 14.40 | −1.12 | 0.261 |
| | | | F | 7 | 10.53±2.41 | 7.60 | 14.60 | | |
| | | Dental Age (noncleft side) | M | 22 | 11.20±1.46 | 8.40 | 14.40 | −1.07 | 0.284 |
| | | | F | 7 | 10.90±2.37 | 7.80 | 14.60 | | |
| | 12-16 | Chronological Age | M | 15 | 13.78±1.15 | 12.00 | 16.00 | −1.5 | 0.113 |
| | | | F | 10 | 14.47±1.26 | 12.50 | 16.08 | | |
| | | Dental Age (cleft side) | M | 15 | 14.40±1.10 | 11.60 | 15.70 | −1.48 | 0.138 |
| | | | F | 10 | 14.60±2.02 | 10.80 | 16.00 | | |
| | | Dental Age (noncleft side) | M | 15 | 14.08±1.12 | 11.60 | 15.70 | −1.31 | 0.191 |
| | | | F | 10 | 14.49±1.63 | 11.80 | 16.00 | | |
| Control | 7-12 | Chronological Age | M | 22 | 10.61±0.89 | 8.00 | 11.92 | −0.765 | 0.444 |
| | | | F | 7 | 10.00±1.35 | 8.33 | 11.66 | | |
| | | Dental Age (Right) | M | 22 | 11.95±1.81 | 8.20 | 15.20 | −0.587 | 0.557 |
| | | | F | 7 | 11.09±2.73 | 8.20 | 14.60 | | |
| | | Dental Age (Left) | M | 22 | 12.02±1.97 | 8.20 | 15.70 | −0.613 | 0.541 |
| | | | F | 7 | 11.09±2.73 | 8.20 | 14.60 | | |
| | 12-16 | Chronological Age | M | 15 | 13.78±1.17 | 12.00 | 15.92 | −1.52 | 0.127 |
| | | | F | 10 | 14.49±1.26 | 12.50 | 16.08 | | |
| | | Dental Age (Right) | M | 15 | 14.43±1.72 | 11.60 | 16.00 | −1.85 | 0.064 |
| | | | F | 10 | 15.41±.98 | 13.50 | 16.00 | | |
| | | Dental Age (Left) | M | 15 | 14.51±1.70 | 11.60 | 16.00 | −1.21 | 0.228 |
| | | | F | 10 | 15.27±.99 | 13.50 | 16.00 | | |

Min: minimum; Max: maximum; SD: standard deviation; M: male; F: female (Mann- Whitney U test)

Sex-based comparisons of the age groups revealed no significant differences in terms of chronological or dental ages in the UCLP and control groups (Table 5).

## DISCUSSION

Although there are many studies in literature that have investigated the correlation between CLP and tooth development, to the best of our knowledge, no studies have been conducted in the Turkish population. In general, previous studies have indicated that there can be differences between ethnicities with respect to dental age or development or both (7-11). Therefore, our study aimed to assess the correlation between dental age of patients and asymmetric dental development in different age groups and to compare our findings with individuals without CLP.

Although delays in dental development in children with CLP was reported to decrease after the age of nine, several studies have shown that this delay may be greater for permanent teeth in older age groups (23, 24). Therefore, we set 12 years as the limit (an inclusion criterion) because permanent dentition is completed by that age. Nonetheless, future studies could be planned to explore different age intervals to reveal more detailed information.

Tan et al. (18) investigated dental development in Singaporean children with UCLP and found that dental age was delayed by 0.55 years compared with the control group, and that asymmetrical dental development was significantly more common in these patients. Asymmetric delays in dental development observed in these individuals were primarily attributed to genetic factors, malnourishment, and insufficient space for tooth growth on the cleft side, as well as reduced blood circulation due to fibrous tissue formation following surgical repair of the cleft and consequent developmental damage to the dental buds. Eerens et al. (16) compared hypodontia, dental age, and asymmetric tooth development between 54 individuals with CLP, 63 of their siblings without cleft, and 250 unrelated individuals without cleft. According to the results of the study, the prevalence of hypodontia and asymmetric tooth development was significantly higher in individuals with CLP and their siblings than in individuals in the control group. No significant difference in dental age was revealed among the three groups. This underlines a close correlation between cleft formation and dental development. In the present study, there was no difference in the dental ages between the right and left sides in individuals with UCLP or those in the control group (Table 2).

Despite the fact that we identified a small degree of dental age retardation on the cleft and noncleft sides in the UCLP group compared with that on the left side in the control group, the difference was not significant (Table 3). Hazza'a et al. (17) reported a significant deviation in dental age between individuals with unilateral and bilateral CLP compared with individuals with no cleft. The authors found that the proportion of dental age retardation was significantly greater in males than in females. According to the researchers, environmental and postnatal developmental factors such as nutritional problems, recurrent respiratory infections, and surgical procedures cause retardation in tooth development in individuals with CLP. Moreover, many genes related to tooth development have been implicated to the development of craniofacial structures. This suggests that genetic mutations that cause CLP may also cause dental development disorders. Altuğ et al. (25) reported that the frequency of the *MSX1* c.*6C>T polymorphism was higher in individuals with CLP and in patients with congenital absence of maxillary lateral teeth than in the normal population; hence, it was speculated that the two conditions may be related.

Several studies have reported that delay in dental development may be greater in children with CLP because of the increasing number of missing teeth (13, 21). According to Lai et al. (21), the etiology of hypodontia alone cannot explain dental delays in children with cleft, because delays in tooth formation have been observed in both cleft and noncleft subjects without hypodontia. Furthermore, Topolski et al. (20) state that the etiologic factors of delayed dental development of individuals with clefts seem to be the same factors responsible for the occurrence of dental anomalies in these individuals, as well as for the manifestation of the cleft itself. However, and although the authors did not observe delayed dental development in the individuals with CLP, this study excluded subjects with agenesis in the mandible. Therefore, the notable absence of delayed dental development in our study and the study by Topoplski et al. (20), as opposed to other studies performed in literature, may be explained by this exclusion criterion.

On the other hand, Pöyry et al. (15) evaluated 131 Finnish children with and without CLP using Demirjian's method and found that 3-9 year old children had a 6-month delay in tooth development, a delay that decreased to 2 months in 8–14 year old children. According to their study, a 2-month delay was also detected in children with cleft lip alone, whereas the authors reported 6.5 and 7 months delays in individuals with UCLP and bilateral CLP, respectively. In our study, we divided the UCLP patients into two age groups: 7–12 and 12–16 years, and we did not observe any differences in dental age between the UCLP and control groups (Table 4). Our findings further revealed no association between dental age and sex in these age groups (Table 5). A recent study has identified retardation of dental age compared with the control group after analyzing the dental age of 108 children with UCLP using Demirjian's and Willems' methods (19). However, both methods revealed discrepancies in determining chronological age, particularly in sex-based comparisons.

Although several previous studies have reported delays in dental development, we failed to detect a significant difference between UCLP and control subjects (15, 17, 18, 21). In line with our findings, Topolski et al. (20) have also reported no significant retardation in dental age in CLP patients compared to control subjects. Furthermore, the authors underline that the differences observed in their study may be explained by the methodological design adopted pertaining to the selected sample size, pairing of the sample, blinding, number of examiners and number of radiograph evaluations per examiner. In addition, we believe that one of the main reasons propelling these differences may be attributed to ethnic and racial differences among study populations. Although the method developed by Demirjian et al. (4) allows a user-friendly determination of the dental age, their model is based on data obtained from French–Canadian children. Consequently, this disputes the applicability and reliability of the method in other ethnicities and has triggered a great deal of controversy in current literature (7-11). Studies conducted in Turkey that investigated dental age in different regions have suggested that Demirjian's method is not a reliable model in the Turkish population. For instance, Özveren & Serindere (11) used the Willems' and Demirjian's methods to assess the dental ages of children in the Aegean region and reported that Demirjian's method was less reliable than the Willems' method in determining the participants' dental age. In addition, Sen Tunç & Koyutürk (8) in their study on children from Northern Turkey and Çelikoğlu et al. (9) in their study on children from Eastern Turkey have both stated that Demirjian's method provided exaggerated results in Turkish children; thus, it may not be suitable for this population. Similarly, we also found that chronological age was lower than the dental age in the control group, and assessments performed in age subgroups showed that chronological age was significantly lower than dental age in individuals with UCLP aged 7-12 years and in control subjects aged 7-12 and 12-16 years.



One of the main limitations of the present study was the unbalanced distribution of gender among groups that can be considered as a prevalent confounding factor. The retrospective nature of our study allowed us to use the panoramic radiographs of patients admitted to our hospital. However, data obtained from a more balanced sample could reflect related differences in a more accurate manner. Our study included 108 individuals, 54 with UCLP and 54 healthy controls. Considering the notable statistically non-significant retardation of dental age in individuals with UCLP, further studies with larger study groups that also investi gate individuals with bilateral CLP will be beneficial. In addition, further studies with equal numbers of subjects are required to reach definitive conclusions.

## CONCLUSION

Based on the results of this study, there was no asymmetric mandibular tooth development detected on the cleft or noncleft side in individuals with UCLP. Moreover, we found no differences in the 7-12 year age group, 12-16 year age group, or between the sexes while comparing the dental ages of these individuals with those of individuals without cleft.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of İstanbul Medipol University School of Dentistry (approval number: 543).

**Informed Consent:** Written informed consent was obtained from the patients who participated in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - E.C. ; Design - E.C. ; Supervision - A.T.A., A.P.M.; Materials -A.T.A., A.P.M; Data Collection and/or Processing - E.C., C.A.; Analysis and/or Interpretation - E.C., C.A.; Literature Search - E.C., C.A., A.T.A., A.P.M; Writing Manuscript - E.C.; Critical Review - A.T.A.

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## REFERENCES

1. Menezes R, Vieira AR. Dental anomalies as part of the cleft spectrum. Cleft Palate Craniofac J 2008; 45: 414-9. [CrossRef]
2. Tortora C, Meazzini MC, Garattini G, Brusati R. Prevalence of abnormalities in dental structure, position, and eruption pattern in a population of unilateral and bilateral cleft lip and palate patients. Cleft Palate Craniofac J 2008; 45: 154-62. [CrossRef]
3. Kaul R, Jain P, Saha S, Sarkar S. Cleft lip and cleft palate: Role of a pediatric dentist in its management. Int J Pedod Rehabil 2017; 2: 1-6. [CrossRef]
4. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973; 45: 211-27.
5. Hägg U, Taranger J. Maturation indicators and the pubertal growth spurt. Am J Orthod 1982; 82: 299-309. [CrossRef]
6. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001; 46: 893-5. [CrossRef]
7. Leurs IH, Wattel E, Aartman IH, Etty E, Prahl-Andersen B. Dental age in Dutch children. Eur J Orthod 2005; 27: 309-4. [CrossRef]
8. Sen Tunc E, Koyutürk AE. Dental age assessment using Demirjian's method on northern Turkish children. Forensic Sci Int 2008; 175: 23-6. [CrossRef]
9. Celikoglu M, Cantekin K, Ceylan I. Dental age assessment: the applicability of Demirjian method in eastern Turkish children. J Forensic Sci 2011; 56: 220-2. [CrossRef]
10. Kırzıoğlu Z, Ceyhan D. Accuracy of different dental age estimation methods on Turkish children. Forensic Sci Int 2012; 216: 61-7. [CrossRef]
11. Ozveren N, Serindere G. Comparison of the applicability of Demirjian and Willems methods for dental age estimation in children from the Thrace region, Turkey. Forensic Sci Int 2018; 285: 38-43. [CrossRef]
12. Tonge CH. Identification of cell patterns in human tooth differentiation. J Dent Res 1967; 46: 876-8. [CrossRef]
13. Ranta R. Comparison of tooth formation in noncleft and cleft affected children with and without hypodontia. ASDC J Dent Child 1982; 49: 197-9.
14. Ranta R. A review of tooth formation in children with cleft lip/palate. Am J Orthod Dentofacial Orthop 1986; 90:11-8. [CrossRef]
15. Pöyry M, Nyström M, Ranta R. Tooth development in children with cleft lip and palate: a longitudinal study from birth to adolescence. Eur J Orthod 1989; 11: 125-30. [CrossRef]
16. Eerens K, Vlietinck R, Heidbüchel K, Van Olmen A, Derom C, Willems G, Carels C. Hypodontia and tooth formation in groups of children with cleft, siblings without cleft, and nonrelated controls. Cleft Palate Craniofac J 2001; 38: 374-8. [CrossRef]
17. Hazza'a AM, Rawashdeh MA, Al-Jamal AL, Al-Nimri KS. Dental development in children with cleft lip and palate: a comparison between unilateral and bilateral clefts. Eur J Paediatric Dent 2009; 10: 90-4.
18. Tan EL, Yow M, Kuek MC, Wong HC. Dental maturation of unilateral cleft lip and palate. Ann Maxillofac Surg 2012; 2: 158-62. [CrossRef]
19. Almotairy N, Pegelow M. Dental age comparison in patients born with unilateral cleft lip and palate to a control sample us-

ing Demirjian and Willems methods. Eur J Orthod 2018; 40: 74-81. [CrossRef]

20. Topolski F, de Souza RB, Franco A, Cuoghi OA, da Silva Assunção LR, Fernandes A. Dental development of children and adolescents with cleft lip and palate. Braz J Oral Sci 2014; 13: 319-24. [CrossRef]
21. Lai MC, King NM, Wong HM. Dental development of Chinese children with cleft lip and palate. Cleft Palate Craniofac J 2008; 45: 289-96. [CrossRef]
22. Cesur E, Altug AT, Toygar-Memikoglu U, Gumru-Celikel D, Tagrikulu B, Erbay E. Assessment of sella turcica area and skeletal maturation patterns of children with unilateral cleft lip and palate. Orthod Craniofac Res 2018; 21: 78-83. [CrossRef]
23. Prahl-Andersen B. The dental development in patients with cleft lip and palate. Trans Eur Orthod Soc 1976; 52: 155-60.
24. Bailit HL, Sung B. Maternal effects on the developing dentition. Arch Oral Biol. 1968; 13: 155-61. [CrossRef]
25. Altug AT, Senol A, Ozkepir NO, Dogan H, Ceylaner S, Ozdiler E. Evaluation of MSX1 gene as the common candidate gene of nonsyndromic congenital hypodontia and cleft lip and palate. J Cleft Lip Palate Craniofac Anomal 2017; 4: 31-7. [CrossRef]

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Original Article

# Buccolingual Inclination Effects of Self-Ligating and Conventional Premolar Brackets: A Cone Beam Computed Tomography Study

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## ABSTRACT

**Objective:** This study aimed to compare the effects of passive self-ligating (PSL) and conventional ligating (CL) of brackets on the buccolingual inclination (BLINC) of the maxillary premolars.

**Methods:** This in vitro study included a PSL bracket group and a CL bracket group. Acrylic teeth on typodonts were aligned using 0.014-inch heat-activated nickel titanium (HANT) (T1) and 0.019×0.025-inch HANT (T2) and 0.021×0.025-inch stainless steel (SS) (T3) archwires in a sequence. Standardized cone beam computed tomography (CBCT) images were taken immediately after each archwire stage. The differences of premolar teeth BLINC values in the 0.019×0.025-inch and 0.014-inch HANT archwires (T2-T1) and 0.021×0.025-inch SS and 0.019×0.025-inch HANT archwires (T3-T2) were compared between PSL and CL groups. The value of $p < 0.05$ was considered statistically significant.

**Results:** The BLINC change of the second premolar (SPM) showed a statistically significant difference (p=0.008), but the BLINC change of the first premolar (FPM) (*p*=0.056) between the groups showed no statistically significant difference during the T2-T1 stage. However, there were statistically significant differences between two groups in the BLINC of the FPM (p=0.032) and SPM (p=0.032) in the T3-T2 stage. The angular changes in the buccal direction in the PSL group were higher than those in the CL group.

**Conclusion:** The PSL upper premolar brackets used with the 0.021×0.025-inch SS archwire produced more buccal crown movement of the upper PM teeth compared with that of the CL brackets.

**Keywords:** Cone beam computed tomography (CBCT), orthodontic brackets, premolar inclination

Main points:

- This in vitro CBCT study aims to compare the effects of PSL and CL brackets on the BLINC of upper premolars.
- In this study, a new method with reference points in the apex and buccal tubercle tips was used to investigate the BLINC of upper premonlars.
- PSL upper premolar brackets used with a 0.021×0.025-inch stainless steel archwire produced more buccal crown movement of the upper premolar teeth compared to that of the CL brackets.

## INTRODUCTION

Orthodontists attempt to properly position the teeth in order to ensure a stable, functional, and aesthetic occlusion. To achieve this treatment goal, the in-out, tip, and torque features must be efficiently expressed by the bracket archwire combinations (1). The change in the labiolingual inclination of a tooth is defined as the torque expression. The wire torque stiffness, the wire size, the bracket slot size, and the mode of ligation affect the torque expression (2-7). In orthodontic literature, most studies used various methods to investigate the torque expression of different bracket systems. These methods included orthodontic measurements and simulation system, finite-element method, radiographs, optical image correlation technique and custom test apparatuse, and cone beam computed tomography (CBCT) records (8-13). CBCT records were used to measure the labiolingual inclination and tip and apex movements of maxillary teeth because three-dimensional (3D) records are crucial to the optimal assessment of the root (8, 14).

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Previous studies on torque measurements have reported the effects of different brackets on incisor inclinations (15-17). However, no study has examined the effects of upper passive self-ligating (PSL) brackets on premolar inclination. Therefore, this in vitro CBCT study aims to compare the effects of PSL and conventional ligating (CL) upper premolar brackets on the buccolingual inclination (BLINC) of these premolars.

## METHODS

The study consisted of a PSL bracket (SmartClip SL3, 3M Unitek, Monrovia, CA, USA) and a CL bracket (Gemini; 3M Unitek, Monrovia, CA, USA) with the same torque values. Conventional nonconvertible upper first molar tubes (3M Unitek) were used. Each bracket had 0.022-inch slots. Table 1 provides information on the brackets. The centers of the clinical crowns were marked, and all upper incisor, canine, and premolar brackets were bonded at a standard height on the acrylic teeth by the same researcher (SY). Class II division 1 occlusion typodonts (Nissin, Kyoto, Japan) with 12 acrylic maxillary teeth (6+6) (Nissin) were used in this in vitro study. Before the teeth were seated in wax, slots of equal size were drilled on the apex and buccal tubercle tips with diamond ball bur. Australian wire of 0.014-inch diameter were bonded to these slots and used as reference points. This made it possible to distinguish the movement of teeth using CBCT imaging (Figure 1). One typodont model was prepared for each group. Ethical approval was not obtained because no patient material was used in this study.

The sample size was determined as per the method described by Katsikogianni et al. (18); five repetitions in each group with 95% confidence interval, 100% test power, and f=9.257 effect size. The teeth were aligned using 0.014-inch heat-activated nickel titanium (HANT) archwires (3M Unitek, Monrovia, CA, USA) (T1), 0.019 × 0.025-inch HANT archwires (3M Unitek, Monrovia, CA, USA) (T2), and 0.021 × 0.025-inch SS archwires (3M Unitek, Monrovia, CA, USA) (T3) in a sequence. A vinyl polysiloxane impression (Zhermack, Badia Polesine RO, Italy) was made just before each archwire application (T1, T2, T3) and used as records of previous maxillary arch forms (19). The typodonts were submerged in 45°C water for 30 minutes during each archwire stage. Five repetitions were performed with five different archwires for every archwire stage. After each archwire was removed, the impression was used to reposition the dentition. A total of 30 bracket-archwire combinations-15 for each group-were tested. With the CL brackets, the archwires were ligated with SS ligatures. The ligature wires were tightened and adjusted so that the wire could be pressed into the slot.

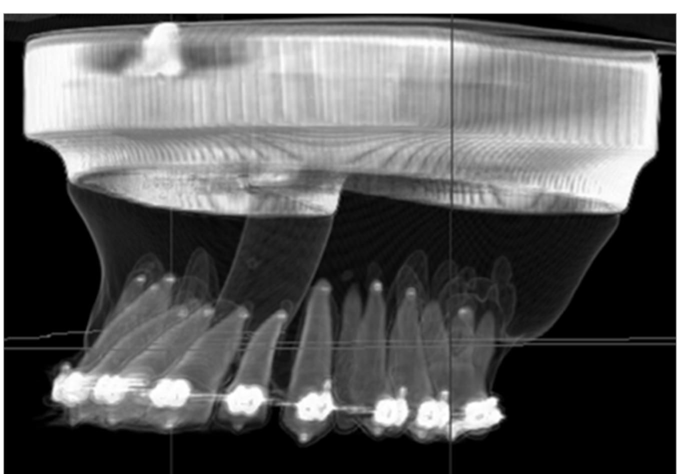

**Figure 1.** The CBCT image with reference points that were bonded to the apex and to the tubercle tips of the premolars

To capture the positional changes of maxillary teeth, standardized CBCT images were taken immediately after the 0.014-inch HANT archwires, 0.019 × 0.025-inch HANT archwires, and 0.021×0.025-inch SS archwires were aligned with the maxillary teeth. A total of 30 CBCT measurements were taken.

The CBCT images were captured using a GALILEOS Comfort PLUS CMCT unit (Sirona Dental Systems Inc., Bensheim, Germany). The settings were as follows: 98 kVp, 25 mAs, 15.4-cm spherical imaging volume field of view, 14-second exposure time, and 0.25 mm isotropic voxel size. Changes in the BLINCs of premolars were measured using the Sidexis XG software package and the Galaxis 3D Viewer (Bensheim, Germany) on CBCT.

To measure the movement of the upper premolar teeth, reference planes were created on cross-sectional profiles of the CBCT images. The long axis of FPM was created between the tooth buccal tip and the buccal apex. The long axis of SPM, created between the tooth buccal tip and the apex, served as a reference for particular degrees of tilt. The angle between the long axis of each tooth and horizontal reference plane of the program used was measured (Figure 2).

### Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA). Compliance with a normal distribution was analyzed using the Shapiro-Wilk test (Table 2). The measurements taken after each archwire application for each bracket system have been presented as median (min-max). Changes in BLINCs of the upper premolar teeth were measured for the 14-inch HANT (T1) and 0.019×0.025-inch HANT (T2) archwires, as well as for the 0.019×0.025-inch HANT (T2) and 0.021×0.025-inch SS (T3) archwires. Intergroup differences were evaluated using the Mann-Whitney *U* test. The value $p<0.05$ was considered as statistically significant.

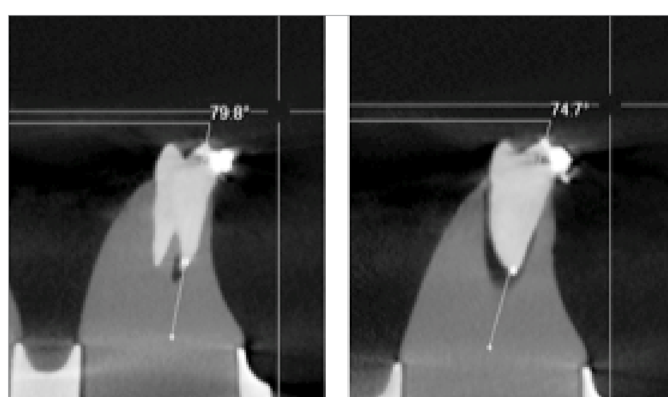


**Figure 2.** The angle between the long axis of the first and second premolars and the horizontal reference plane, respectively.

**Table 1.** The prescriptions of the brackets in this study

| Tooth | Bracket group | Slot width (inch) | Torque (°) | Angulation (°) | In/Out (inch) |
|---|---|---|---|---|---|
| FPM | PSL | 0.022 | -7 | 0 | 0.036 |
| | CL | 0.022 | -7 | 0 | 0.030 |
| SPM | PSL | 0.022 | -7 | 0 | 0.036 |
| | CL | 0.022 | -7 | 0 | 0.040 |

FPM: first premolar; SPM: second premolar; PSL: passive self-ligating; CL: conventionally ligating

**Table 2.** Test of normality

| Bracket group | Time | Tooth | Test statistics | SD | p |
|---|---|---|---|---|---|
| PSL | T1 | FPM | 0.884 | 5 | 0.326 |
| | | SPM | 0.854 | 5 | 0.207 |
| | T2 | FPM | 0.799 | 5 | 0.079 |
| | | SPM | 0.948 | 5 | 0.725 |
| | T3 | FPM | 0.914 | 5 | 0.492 |
| | | SPM | 0.883 | 5 | 0.324 |
| CL | T1 | FPM | 0.845 | 5 | 0.179 |
| | | SPM | 0.778 | 5 | 0.075 |
| | T2 | FPM | 0.798 | 5 | 0.078 |
| | | SPM | 0.817 | 5 | 0.111 |
| | T3 | FPM | 0.881 | 5 | 0.314 |
| | | SPM | 0.982 | 5 | 0.945 |

SD: standard deviation



**Table 3.** Comparison of the differences in BLINC between different bracket groups with Mann Whithey U test

| | T2-T1 Median (min: max) | | | T3-T2 Median (min: max) | | |
|---|---|---|---|---|---|---|
| Tooth | PSL | CL | p | PSL | CL | p |
| FPM BLINC (°) | 0,6 (-0,7:0,8) | 1,4 (-0,2:3,2) | NS | -0,3 (-1,6:0,7) | 1,9 (0,2:2,0) | 0,032 |
| SPM BLINC (°) | -0,5 (-3,3:0) | 1,3 (1:2,3) | 0,008 | -2,1 (-3,7:-0,5) | -0,5 (-1,8:0,8) | 0,032 |

BLINC: buccolingual inclination; NS: nonsignificant; significant at p<0.05

The measurement errors were calculated using the Dahlberg formula ($Se=\sqrt{\Sigma d^2/2n}$), with 0.87° for angular measurements.

## RESULTS

The differences of premolar teeth BLINC values in the 0.019×0.025-inch and 0.014-inch HANT archwires (T2-T1) and 0.021×0.025-inch SS and 0.019×0.025-inch HANT archwires (T3-T2) were compared among PSL and CL groups. The results have been presented in Table 3.

The BLINC change of the second premolar (SPM) showed statistically significant difference (p=0.008), but the BLINC change of the first premolar (FPM) (p=0.056) showed no statistically significant difference between the groups during the T2-T1 stage. There were statistically significant inter-group differences in BLINC of the FPM (p=0.032) and SPM (p=0.032) in the T3-T2 stage.

## DISCUSSION

In this experimental study, we used 0.014-inch HANT, 0.019×0.025-inch HANT, and 0.021×0.025-inch SS archwires. Although 0.021×0.025-inch SS archwire is not routinely used in clinical practice, this archwire reflects the torque values of the brackets better because the engagement angle decreased by 6° when a 0.021×0.025-inch SS archwire was used (3, 20). According to Alexander, 5° of effective torque were lost with every 0.001-inch gap between the vertical slot and the archwire (21).

In the PSL group, in the T2-T1 stage, while the SPM was angled in the buccal direction, the FPM showed angulation in palatinal direction parallel to the torque value of the bracket. In the T3-T2 stage, the BLINC changes of the FPM and SPM were in the buccal direction. The angular changes in the PSL group were statistically significantly higher than those in the CL group. It has been suggested that this angulation is formed in the opposite direction according to the torque value of the bracket. This may be caused by the deterioration of the relationship with the slot base and archwire as the posterior tooth sequence goes distally and as the stiffness of the archwire increases. In the CL group, in the T2-T1 stage, although the BLINCs of the FPMs and SPMs changed in the palatinal direction, in the T3-T2 stage, the fact that the SPM was opened in the buccal direction also supports this view. The CL premolar brackets were more compatible with the torque value of the brackets than the PSL brackets, particularly in the T2-T1 stage. This can be explained by the ligation form of the premolar brackets. The compression fitting of the SS ligatures used with the CL brackets may have resulted in the archwire better fitting into the slot. Fischer-Brandies et al. (6) also reported that using SS ligatures decreased the clearance between the slot and archwire, even with space between them. Al-Thomali et al. (22) concluded that CL brackets had higher torque expression than self-ligating brackets. Huang et al. (10) reported that self-ligating Damon and Speed brackets had lower torque capabilities compared to those of conventional Discovery brackets. In contrast, Katsikogianni et al. (18) reported that CL brackets had lower torque capabilities than those of the self-ligating brackets. According to Yeh et al. (23), torque control in PSL brackets was similar to that in the CL brackets. Fleming et al. (24) were reported that no significant differences were found in the inclination changes of the molar and incisor between the CL brackets and either active or passive SL. Lineberger et al. (25) reported no significant changes on crown torque for any teeth, with the exception of maxillary premolars, which showed a significant increase on the buccal crown torque in a PSL system.

In orthodontic treatment, clinical and physiological factors may cause a variety of clinical responses to a bracket archwire combination. Therefore, this in vitro study cannot fully represent a clinical reality. The findings of this study may be supported or rejected by the findings of future clinical studies on the inclination effects of various bracket archwire combinations.

## CONCLUSION

Based on the findings of this in vitro study, PSL upper premolar brackets used with a 0.021 × 0.025-inch SS archwire produced more buccal crown movement of the upper premolar teeth compared to that of the CL brackets.

**Ethics Committee Approval:** Ethical approval was not obtained because no patient material was used in this in vitro study.

**Informed Consent:** N/A.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Conception - S.Y.; Design - S.Y., S.A., M.Ö.; Supervision - S.A., M.Ö.; Data Collection and/or Processing - S.Y., A.A.Ö., N.A.; Analysis and/or Interpretation - A.Z.Ö., N.A.; Writing Manuscript - S.Y., A.A.Ö., A.Z.Ö.; Critical Review - S.A., M.Ö.; Literature Search - A.Z.Ö., A.A.Ö., N.A.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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## REFERENCES

1. McLaughlin RP, Bennett JC, Trevisi HJ. Systemized orthodontic treatment mechanics. Elsevier Health Sciences; 2001.
2. Morina E, Eliades T, Pandis N, Jäger A, Bourauel C. Torque expression of self-ligating brackets compared with conventional metallic, ce¬ramic, and plastic brackets. European J Orthod 2008; 30: 233-8. [Crossref]
3. Archambault A, Lacoursiere R, Badawi H, Major PW, Carey J, Flores-Mir C. Torque expression in stainless steel orthodontic brackets. A systematic review. Angle Orthod 2010; 80: 201-10. [Crossref]
4. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. J Orthod 2010; 37: 241-9. [Crossref]
5. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot in orthodontic brackets - are standards as expected? Angle Orthod 2004; 74: 450-3.
6. Fischer-Brandies H, Orthuber W, Es-Souni M, Meyer S. Torque transmission between square wire and bracket as a function of measurement, form and hardness parameters. J Orofac Orthop 2000; 61: 258-65. [Crossref]
7. Harzer W, Bourauel C, Gmyrek H. Torque capacity of metal and polycarbonatebrackets with and without a metal slot. Eur J Orthod 2004; 26: 435-41. [Crossref]
8. Lee RJ, Pham J, Choy M, Weissheimer A, Dougherty HL Jr, Sameshima GT, et al. Monitoring of typodont root movement via crown superimposition of single cone-beam computed tomography and consecutive intraoral scans. Am J Orthod Dentofacial Orthop 2014; 145: 399-409. [Crossref]
9. Li Y, Tang N, Xu Z, Feng X, Yang L, Zhao Z. Bidimensional techniques for stronger anterior torque control in extraction cases: A combined clinical and typodont study. Angle Orthod 2011; 82: 715-22. [Crossref]
10. Huang Y, Keilig L, Rahimi A, Reimann S, Eliades T, Jäger A, et al. Numeric modeling of torque capabilities of self-ligating and conventional brackets. Am J Orthod Dentofacial Orthop 2009; 136: 638-43. [Crossref]
11. Sangcharearn Y, Ho C. Effect of incisor angulation on overjet and overbite in class II camouflage treatment: A Typodont Study. Angle Orthod 2007; 77: 1011-8. [Crossref]
12. Lacoursiere RA, Nobes DS, Homeniuk DL, Carey JP, Badawi HH, Major PW. Measurement of orthodontic bracket tie wing elastic and plastic deformation by arch wire torque expression utilizing an optical image correlation technique. J Dent Biomechanics 2010; 1: 397037. [Crossref]
13. Sifakakis I, Pandis N, Makou M, Eliades T, Katsaros C, Bourauel C. Torque expression of 0.018 and 0.022 inch conventional brackets. Eur J Orthod 2013; 35: 610-14. [Crossref]
14. Tong H, Enciso R, Van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2012; 142: 133-43. [Crossref]
15. Isaacson RJ, Lindauer SJ, Rubenstein LK. Moments with the edgewise appliance: incisor torque control. Am J Orthod Dentofacial Orthop 1993; 103: 428-38. [Crossref]
16. Liang W, Rong Q, Lin J, Xu B. Torque control of the maxillary incisors in lingual and labial orthodontics: a 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2009; 135: 316-22. [Crossref]
17. Pandis N, Strigou S, Eliades T. Maxillary incisor torque with conventional and self-ligating brackets: a prospective clinical trial. Orthod Craniofac Res 2006; 9: 193-8. [Crossref]
18. Katsikogianni EN, Reimann S, Weber A, Karp J, Bourauel C. A comparative experimental investigation of torque capabilities induced by conventional and active, passive self-ligating brackets. Eur J Orthod 2014; 37: 440-6. [Crossref]

19. Lia Y, Tangb N, Xub Z, Fengb X, Yangb L, Zhaoc Z. Bidimensional techniques for stronger anterior torque control in extraction cases: a combined clinical and typodont study. Angle Orthod 2012; 82: 715-22. [Crossref]
20. Badawi HM, Toogood RW, Carey JP, Heo G, Major PW. Torque expression of self-ligating brackets. Am J Orthod Dentofacial Orthop 2008; 133: 721-8. [Crossref]
21. Alexander R. The Alexander Discipline: The 20 Principles of the Alexander Discipline. Quintessence Publ. 2008.
22. Al-Thomali Y, Mohamed RN, Basha S. Torque expression in self-ligating orthodontic brackets and conventionally ligated brackets: a systematic review. J Clin Exp Dent 2017; 9: e123-8.
23. Yeh C-L, Kustano B, Viana G, Evans CA, Drummond JL. In-vitro evaluation of frictional resistance between brackets with passive-ligation designs. Am J Orthod Dentofacial Orthop 2007; 131: 704.e11-22. [Crossref]
24 Fleming PS, Lee RT, Marinho V, Johal A. Comparison of maxillary arch dimensional changes with passive and active self-ligation and conventional brackets in the permanent dentition: a multicenter, randomized controlled trial. Am J Orthod Dentofacial Orthop 2013; 144: 185-93. [Crossref]
25. Lineberger MB, Franchi L, Cevidanes LHS, Ghislanzoni LTH, McNamara Jr JA. Three-dimensional digital cast analysis of the effects produced by a passive selfligating system. Eur J Orthod 2016; 38: 609-14. [Crossref]

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Original Article

# Bond Strength of Metal and Ceramic Brackets on Resin Nanoceramic Material With Different Surface Treatments

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## ABSTRACT

**Objective:** This study aimed to evaluate the effects of different surface conditoning methods on surface texture and shear bond strength (SBS) of brackets bonded to resin nanoceramic material.

**Methods:** Ceramic specimens were divided into two groups as metal brackets and ceramic brackets. In each group, the following five subgroups were conditoned with orthophosphoric acid (OPA), hydrofluoric acid (HFA), silica coating with Cojet, Nd: Yag laser, and Femtosecond (Fs) laser. Extra samples were used for scanning electron microscopy and 3D profilometer evaluation.

**Results:** All surface conditioning methods caused optimum or higher SBS. Metal brackets had higher SBS than porcelain brackets, but this difference reached statistical significance only in Fs laser group. OPA caused surface modification comparable to HFA because of polymer content of resin nanoceramic. Although Fs laser and Cojet conditioning caused optimum or higher SBS, surface damage of these methods to the resin nanoceramic specimens clearly seen on 3D profilometer.

**Conclusion:** HFA and Nd: Yag laser are effective surface conditioning methods for resin nanoceramics. OPA combined with silane application caused optimum SBS and can be used as an alternative to HFA. Surface texture changes should be considered to determine surface damage while deciding the optimum surface conditioning method for ceramics other than SBS.

**Keywords:** Dental materials, lasers, orthodontic brackets

Main points:

- Conventional acid etching methods are effective conditioning methods for resin nanoceramic surfaces.
- Nd: Yag laser provided optimum SBS, surface roughness and PFI scores and could be used as ideal surface treatment method for resin nanoceramics.
- Although obtaining high SBS, methods causing high surface roughness ought to be disregarded by clinicians in order not to face repairs or renewals after debonding.
- Due to the high ceramic fracture rates seen in this study, clinicians should approach with caution to the resin nanoceramic restorations and inform patients about failure risks prior to bracket bonding.

## INTRODUCTION

With the current increase in adult patients seeking orthodontic treatments, orthodontists are more concerned about bonding orthodontic brackets other than enamel surfaces. Bonding ceramic surfaces are one of the reasons for this concern because a certain conditioning protocol could not be applied because of the material composition differences (1). Different mechanical and chemical conditioning methods and their combinations have been suggested to overcome this problem (2). Mechanical methods such as sandblasting and roughening with diamond burs require special tools and might cause damage to ceramic surfaces (3), chemical methods such as hydrofluoric acid (HFA) has found to be harmful and can cause tissue irritation (4).

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In recent years, lasers are used to overcome these disadvantages. Studies have been conducted using $CO_2$, Er: Yag, Nd: Yag, and Femtosecond (Fs) lasers, and researchers stated that these have been useful alternatives for conventional conditioning methods (5, 6).

The demand for aesthetic restorations with the advances in software and milling devices has encouraged the research and development processes of more advanced porcelain systems using computer-aided design and computer-aided manufacturing (CAD/CAM) (7). Resin-matrix CAD/CAM ceramics have been developed to combine the advantageous properties of ceramics, such as durability and color stability, with those of composite resins, such as improved flexural properties and low abrasiveness (8). Composite resin nanoceramic CAD/CAM blocks consist of a polymeric matrix reinforced by nanohyrbrid ceramic fillers containing 71% by weight (7). Industrial fabrication of these materials at a high temperature and high pressure significantly improves their mechanical behavior (9, 10). To the best of our knowledge there, has been no report on bond strength of brackets bonded to resin nanoceramic CAD/CAM material.



There are many shear bond strength (SBS) studies in the literature, suggesting different conditioning methods for bonding brackets to ceramic surfaces using scanning electron microscopy (SEM) to determine surface texture changes (2, 5, 11). These studies mostly focused on attaining the highest SBS results and disregarded the possible irreversible surface texture changes, which are secondary to the conditioning methods. 2D SEM images alone are insuffcient to assess these changes and there is only one study in the literature assessing ideal surface conditioning method with regards to SBS and 3D surface texture changes (12).

This study aimed to determine the ideal method for optimum SBS without causing irreversible surface damage for clinicians by evaluating the effect of surface treatments with the perspectives not only considering shear bond strength of ceramic and metal brackets, but also surface texture changes due to surface conditioning on resin nanoceramic CAD/CAM restorative material. The effect of conditioning with Ti: sapphire Fs laser, Nd: Yag laser, tribochemical coating, and conventional acid etching methods were evaluated using a shear bond test, 3D profilometer, and SEM as surface imaging techniques. The null hypotheses of this study were that type of bracket and type of surface treatment would not affect the SBS of brackets bonded to resin nanoceramics and surface treatment methods would not cause irreversible surface damage to resin nanoceramics.

## METHODS

No ethical approval required for the study because of *in vitro* design and testing of a dental material already in use. For a power of 0.95 with the significance level $p<0.05$, a sample of at least 15 ceramics for each group would be required based on study by Erdur et al. (5). For this reason, 17 ceramics per group were prepared.

A total number of 170 specimens (15 mm×10 mm×2 mm) were prepared from resin nanoceramic CAD/CAM blocks (Cerasmart, GC Europe, Belgium). These, 170 specimens divided into two groups as metal and porcelain brackets and each group were further divided into five subgroups.

Fs laser group: Selcuk University ILTEK research facility's Ti: sapphire Fs laser (λ=800 nm; Quantronix, Integra-C-3.5, NY, USA) was used (5). The laser scan was applied five times to the whole geometry. The scan pattern consisted of individual parallel horizontal lines with line gap of 30 µm. At the end of each line, the laser is automatically switched off and moves to the next line. The fluence for 90 Fs pulse width, 0.05 W power, and 11 cm focal length settings was $2,77\times10^{1}$ J/cm$^2$ (Figure 1a).

A pilot study was conducted to obtain optimum laser parameters for resin nanoceramic specimens to minimize ablation rate and homogenize surface conditioning patterns. Power settings and line gaps changing between 0.05-0.75 W and 10-30-50 µm with five scans were examined by SEM and 3D profilometer. Stated parameters were chosen after the pilot study.

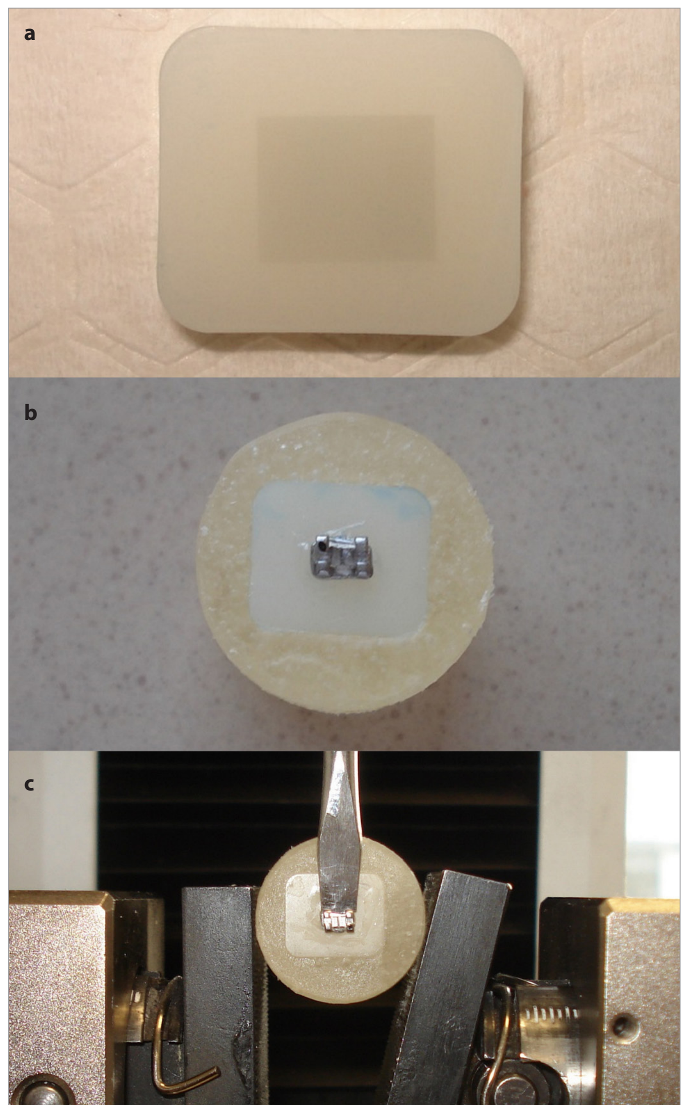


**Figure 1. a-c.** Specimen images of in vitro design (a), a specimen of Fs laser conditioned group ready for silanization (b), a specimen embedded in acrylic resin bloc (c), a specimen ready for SBS test

Nd: Yag laser group: Nd: Yag laser (Fotona, Horse Fidelis, Ljubljana, Slovenia) was applied using a 300-µm diameter optical fiber perpendicular to the ceramic surface. The output settings were 2 W and medium-short pulse mode, with 20 seconds application time, at a focal distance of 1 mm using a noncontact hand piece (5).

Cojet group: Air abrasion with 30-µm $Al_2O_3$ particles coated with silica using CoJet System (3M Espe, St. Paul, MN, USA) was applied to the specimens for 5 seconds at a pressure of 2.8 bar (13). The distance between the nozzle and the surface of the ceramic was approximately 10 mm (14). The sand particle remnants were gently air blown.

HFA group: The ceramic surfaces were etched with 9% HFA (Porch-Etch, Reliance Orthodontic Products, USA) for 60 seconds. Then, the acid was rinsed off with water for 60 seconds (5).

Orthophosphoric acid (OPA) group: The ceramic surfaces were etched with 37% OPA (Best Blue Gel, Spot Dis Deposu, Izmir, Turkey) for 60 seconds (6). Then, the acid was rinsed off with water for 60 seconds.

After surface conditioning, silane (Reliance porcelain conditioner, Reliance, IL, U.S.A.) was applied to the treated ceramic surfaces. In total, 85 maxillary central metal brackets (Mini Master Series, American Orthodontics, WI, USA) and 85 porcelain brackets (20/40, American Orthodontics, WI, USA) were bonded randomly with adhesive resin (Transbond XT, 3M Unitek, CA, USA) to the ceramic surfaces. With the aid of a probe, the excess resin was removed. Then, the adhesive resin was light cured for 10 seconds using an LED unit (Valo cordless, Ultradent, USA, standart mode-1000mW/cm$^2$). All bonding operations were performed by the same operator (M.K.).

After the bonding procedure, the specimens were stored in distilled water at room temparature for at least 24 hours and, then, thermocycled for 1,000 cycles between 5°C and 55°C with a dwell time 25 seconds in a thermocycler (Julabo, Seelbach, Germany). Then, the specimens were embedded in acrylic resin blocks (Imicryl, Konya, Turkey) (Figure 1b). The SBS test was performed using a universal testing device (Instron 3345, USA) at a crosshead speed of 0.5 mm/min (Figure 1c) (11). The force required for debonding was obtained in Newtons (N) and converted into megapascals (MPa). The bracket base areas for the American Orthodontics metal brackets and ceramic brackets were 10.9 and 13.2 mm$^2$, respectively.

After surface roughening, the average surface roughness of chosen conditioned and nonconditioned ceramic specimens were evaluated with a profilometer (AEP NanoMap-LS, CA, USA). A diamond stylus (tip radius, 5 µm) acted across the surface under a continuous charge of 40 mg with a speed of 40 µm/s and a range of 500 µm, to measure the roughness value in µm. For each measurement, the device performs random 30 probing around the perimeter of a 500-µm line and calculates mean roughness. Two extra specimens from each surface conditioning group with two measurements were planned at the beginning of the study. However, after obtaining elevated SBS results, the addition of a nonconditioned specimen with four measurement was decided for 3D profilometer evaluation to clarify the exact surface texture changes. In total, means of four measurements from each group were calculated from the center area of specimens. For Fs laser group, two additional measurements for each specimen were made from the laser conditioned border area to determine the ablation amount. No sample size calculation has been conducted for profilometric evaluation.

Following surface roughening, one specimen from each conditioned and nonconditoned groups was selected randomly, and all specimens were sputter-coated with gold-palladium and evaluated using a SEM (Jeol JMS-6390LV, Jeol, Tokyo).

After SBS test, the ceramic surfaces underwent surface morphological analyses using a stereomicroscope (Leica M50, Wetzlar/Germany) at 25× magnification to determine the amount of composite resin remaining according to the Adhesive Remnant Index (ARI) proposed by Artun and Bergland (15) scoring as: 0-no adhesive remaining on the ceramic surface; 1-less than 50% adhesive remaining on the ceramic; 2-more than 50% adhesive remaining on the ceramic; and 3-100% adhesive remaining on the ceramic, with a distinct impression of the bracket mesh.



Any damage that may have occured to the ceramic surfaces during SBS testing was recorded using the Porcelain Fracture Index (PFI) proposed by Bourke and Rock (16) scoring as: 0-ceramic surface intact or in the same condition as before the bonding; 1-surface damage limited to very superficial ceramic; 2-surface damage which features significant loss of ceramic requiring restoration of the defect by composite resin or replacement of the restoration; and 3-surface damage where the core material has been exposed.

For the Statistical Package for Social Sciences, version 15.0 software (SPSS Inc.; Chicago, IL, USA). Kolmogorov-Smirnov Test was used to verify normality distrubution of test values. Two-way analysis of variance (ANOVA) was used to check the effect of type of bracket, type of surface treatment, and their interaction. Tukey's honestly significantly different test was used to compare SBS among the groups. Chi-square ($\chi^2$) test was used to determine if there were any significant differences in the ordinal ARI and PFI values. Nonparametric Wilcoxon signed-rank test was used to compare surface roughness values. Statistical significance was set at the 0.05 probability level.

## RESULTS

According to two-way ANOVA type of bracket, type of surface treatment and their interaction significantly affected the SBS test (Table 1).

The SBS for the study groups are shown in Table 2. The mean SBS values of the metal bracket groups ranged from 8.66 to 13.02 MPa. HFA, Cojet, and Fs laser groups have significantly higher mean SBS than Nd: Yag laser group. The mean SBS values of the porcelain bracket groups ranged from 9.36 to 10.91 MPa. There were no significant differences between study groups. Except for Nd: Yag laser group, all metal bracket groups showed

**Table 1.** Two-way ANOVA results for the type of bracket, type of treatment, and the interaction terms according to bond strength data (MPa).

| Effect | df | Sum of squares | Mean square | F ratio | p |
|---|---|---|---|---|---|
| Bracket type | 1 | 97.799 | 97.799 | 12.095 | .001* |
| Surface conditioning | 4 | 150.517 | 37.629 | 4.654 | .001* |
| Bracket type x surface conditioning | 4 | 138.795 | 34.699 | 4.291 | .003* |

*p<0.05

**Table 2.** Mean, standard deviation (SD), minimum (min.)-maximum (max.), and median of the SBS (MPa) according to the surface treatments.

| Surface treatment | Metal bracket | SD | Min.-Max. | Median | Porcelain bracket | SD | Min.Max. | Median |
|---|---|---|---|---|---|---|---|---|
| Orthophosphoric acid | 10.32A[Bc] | 3.65 | 15.86-2.96 | 10.37 | 9.36[Ac] | 2.81 | 4.91-12.64 | 9.55 |
| Hydrofluoric acid | 13.02[Ac] | 2.27 | 9.38-15.96 | 13.20 | 10.91[Ac] | 1.60 | 13.34-8.66 | 10.84 |
| Cojet | 12.70[Ac] | 4.31 | 4.36-19.68 | 12.53 | 9.81[Ac] | 3.90 | 2.49-17.06 | 9.90 |
| Nd:Yag laser | 8.66[Bc] | 2.13 | 12.57-4.41 | 8.56 | 10.38[Ac] | 1.98 | 6.81-13.20 | 10.44 |
| Fs laser | 13.01[Ac] | 2.43 | 9.31-16.63 | 12.72 | 9.68[Ad] | 1.95 | 5.64-12.44 | 9.65 |

Mean values represented with same superscript upper-case letter (column) are not significantly different according to Tukey test (p>0.05); mean values represented with different superscript lower-case letter (row) are significantly different according to Tukey test (p<0.05)



**Table 3.** Frequency distribution of adhesive remnant index (ARI) scores.

| | ARI scores | | | |
|---|---|---|---|---|
| Group | 0 | 1 | 2 | 3 |
| Metal bracket | | | | |
| Orthophosphoric acid | 0 | 7 | 2 | 8 |
| Hydrofluoric acid | 0 | 13 | 1 | 3 |
| Cojet | 1 | 9 | 0 | 7 |
| Nd:Yag laser | 15 | 1 | 0 | 1 |
| Fs laser | 3 | 4 | 3 | 7 |
| Porcelain bracket | | | | |
| Orthophosphoric acid | 1 | 12 | 2 | 2 |
| Hydrofluoric acid | 0 | 8 | 9 | 0 |
| Cojet | 0 | 7 | 7 | 3 |
| Nd:Yag laser | 7 | 8 | 2 | 0 |
| Fs laser | 0 | 7 | 6 | 4 |

0-no adhesive remaining on the ceramic surface
1-less than 50% adhesive remaining on the ceramic surface
2-more than 50% adhesive remaining on the ceramic surface
3-100% adhesive remaining on the ceramic surface, with a distinct impression of the bracket mesh

**Table 4.** Frequency distribution of porcelain fracture index (PFI) scores.

| | PFI scores | | | |
|---|---|---|---|---|
| Group | 0 | 1 | 2 | 3 |
| Metal bracket | | | | |
| Orthophosphoric acid | 13 | 1 | 3 | 0 |
| Hydrofluoric acid | 16 | 1 | 0 | 0 |
| Cojet | 11 | 2 | 4 | 0 |
| Nd:Yag laser | 17 | 0 | 0 | 0 |
| Fs laser | 8 | 2 | 7 | 0 |
| Porcelain bracket | | | | |
| Orthophosphoric acid | 13 | 2 | 2 | 0 |
| Hydrofluoric acid | 15 | 1 | 1 | 0 |
| Cojet | 8 | 3 | 6 | 0 |
| Nd:Yag laser | 16 | 1 | 0 | 0 |
| Fs laser | 4 | 5 | 8 | 0 |

0-ceramic surface intact or in the same condition as before the bonding
1-surface damage limited to very superficial ceramic
2-surface damage which features significant loss of ceramic requiring restoration of the defect by composite resin or replacement of the restoration
3-surface damage where the core material has been exposed

**Table 5.** Mean, standard deviation (SD), minimum (min.)-maximum (max), and median values of surface roughness (µm) according to the surface treatments

| Group | Mean surface roughness | SD | Min.-Max. | Median |
|---|---|---|---|---|
| No treatment | 0.031[a] | 0.006 | 0.021-0.036 | 0.033 |
| Orthophosphoric acid | 0.084[b] | 0.009 | 0.071-0.092 | 0.088 |
| Hydrofluoric acid | 0.108[b] | 0.024 | 0.084-0.140 | 0.104 |
| Cojet | 0.690[c] | 0.143 | 0.515-0.823 | 0.711 |
| Nd:Yag laser | 0.100[b] | 0.009 | 0.092-0.112 | 0.097 |
| Fs laser | 0.309[d] | 0.029 | 0.286-0.347 | 0.301 |

Mean values represented with different superscript lower-case letter are significantly different according to Wilcoxon signed-rank test (p<0.05)

higher mean SBS compared with porcelain bracket groups. This difference reached statistical significance only in Fs laser group (p<0.05).

Bond failure modes are shown in Table 3. Except for Nd: Yag porcelain/OPA porcelain groups (p>0.05), the ARI scores showed that adhesive failures between the ceramic and com-

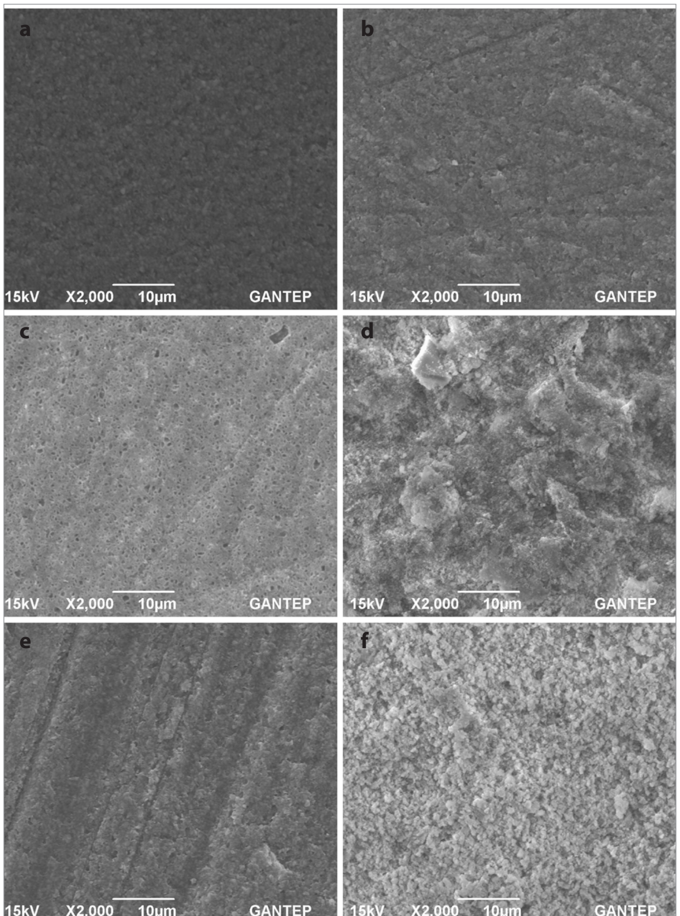


**Figure 2. a-f.** SEM surface images of treated and non-treated resin nano-ceramics (x2000 magnification) (a) Non-treated (b) OPA (c) HFA (d) Cojet (e) Nd: Yag laser (f) Fs laser

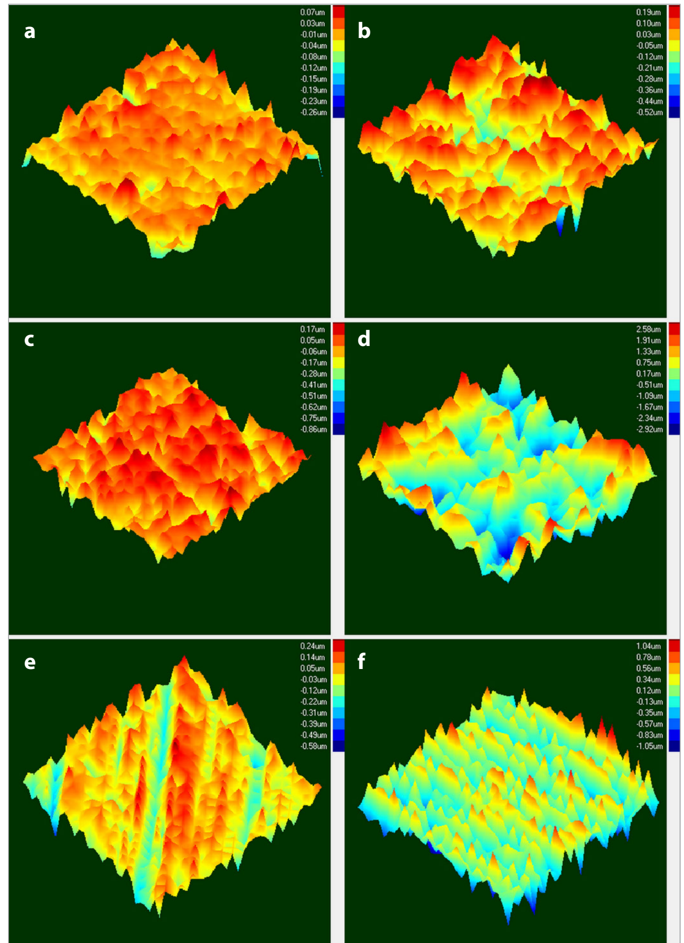


**Figure 3. a-f.** 3D profilometer images of treated and nontreated resin nanoceramics, (a) Nontreated (Maximum height 0.092 µm, minimum height –0.264 µm). (b) OPA (Maximum height 0.265 µm, minimum height –0.517 µm). (c) HFA (Maximum height 0.281 µm, minimum height -0.483 µm). (d) Cojet (Maximum height 2.472 µm, minimum height –2.924 µm). (e) Nd: Yag laser (Maximum height 0.325 µm, minimum height -0.461 µm). (f) Fs laser (Maximum height 0.959 µm, minimum height –1.051 µm).

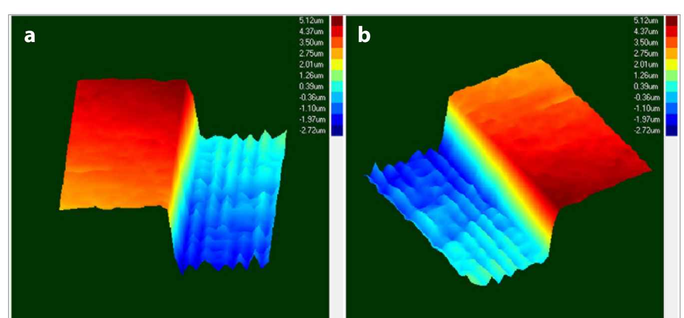


**Figure 4. a-b.** Images of ablated and nonablated border area of Fs laser trated resin nanoceramic from different angles. Maximum height 5.116 µm, minimum height –2.348 µm. Peak to peak difference 7.463 µm.

posite resin were the predominant mode of failure in Nd: Yag laser groups ($p<0.05$). For other study groups, a failure mode shift between composite resin and bracket base were observed especially in Fs laser groups compared with Nd: Yag laser groups ($p<0.05$).

Porcelain fracture modes are shown in Table 4. Except for Cojet metal/Nd: Yag porcelain groups ($p>0.05$), the highest incidence of cohesive fracture of resin nanoceramics were observed in Fs laser and Cojet groups, the lowest incidence observed in Nd: Yag laser groups ($p<0.05$).

Representative SEM images of the treated and nontreated resin nanoceramics are presented in Figure 2. Homogenous microporous surface texture of the nontreated specimen showed a variation in the surface microstructure with the surface treatments. Due to the partial dissolving of organic component of resin nanoceramic, OPA showed minimal erosive areas. HFA effecting both organic and inorganic components of resin nanoceramic showed erosive areas and randomly distributed micropores. Silica-coating produced random surface peeling and well-defined microsize elevation and depression areas. Nd: Yag laser produced undulated surface morphology with sulcular appearance. Fs laser produced uniform micro and nano roughnesses without crack formation on the surface.

Representative 3D profilometer images of the conditioned and nonconditioned resin nanoceramics are presented in Figure 3. 3D profilometer images of laser conditioned and nonconditioned border area of Fs laser treated resin nanoceramic are presented in Figure 4. Compared to nonconditioned specimen minimum and maximum height changes can be clearly seen in

Figure 3 caused by surface conditioning methods. Cojet produced the highest increase of minimum and maximum height levels, which can be speculated as a sign of maximum increase of surface roughness (Figure 3d). OPA, HFA, and Nd: Yag laser groups showed comparable minimum and maximum height changes, which could be interpreted as a sign of similar surface roughness values (Figures 3b, 3c, and 3e). Specific to Fs laser group, ~ 5 µm ablation was observed at the border of the laser conditioned and nonconditioned areas (Figure 4).

Mean roughness values (µm) are shown in Table 5. All surface conditioning methods caused significant increase in surface roughness compared with nonconditioned specimen according to Wilcoxon signed-rank test. The surface roughnesses of the conditioned resin nanoceramics indicated significant differences among the groups ($p<0.05$). Cojet caused a significantly higher mean surface roughness compared with other surface treatments. Fs laser midsection roughness value is significantly lower than Cojet and significantly higher than OPA, HFA, and Nd: Yag laser groups ($p<0.05$). There was no statistically significant difference between OPA, HFA, and Nd: Yag laser groups ($p>0.05$).



## DISCUSSION

The results of this study demonstrated no significant SBS differences between the metal and ceramic brackets; therefore, the first null hypothesis was accepted. The results of this study demonstrated significant SBS differences among surface conditioning groups; therefore, the second null hypothesis was rejected. The results of this study demonstrated significant surface texture changes depending on conditioning methods; therefore, the third null hypothesis was rejected.

CAD/CAM systems registered a constantly increasing use in dentistry. This technology allows a completely digital workflow, from impression to final framework, with acceptable clinical reliability (17), good aesthetics (18), and excellent patients feedback (19). However, only few studies tested the bond strength of orthodontic appliances on these recently introduced materials (13); hence, this study was planned and performed to specify the most reliable surface treatment method for bonding ceramic and metal brackets onto resin nanoceramic CAD/CAM material with regards to SBS values for bonded brackets, ARI and PFI scores, SEM images, and 3D profilometer analyses. Thermocycling procedure was applied to the specimens before SBS testing as a screening procedure for the performance of the bonded interfaces under standardized hydrothermal stresses (13). SBS test was used to evaluate the bond strength between resin nanoceramic material and brackets. Although the clinical implications of *in vitro* studies are questionable, they are the first choice in testing new materials and methods before they can be used *in vivo*.

In accordance with previous studies, before bonding procedure, a silane coupling agent was applied to increase wettability and the bonding of resin to ceramics after surface conditioning (1).

In the literature, there are no clear guidelines about shear force limits, but in fact a good orthodontic biomaterial should allow good adhesion in order to sustain masticatory forces (5-10 MPa). In contrast, adhesion forces should not be too strong in order to avoid enamel loss after debonding (40-50 MPa). Therefore, the ideal orthodontic biomaterial should have bonding forces included in the interval of 5-50 MPa for enamel bonding, even if these limits are mostly theoretical (20). But for ceramic restorations, it was reported that bond strength values over 13 MPa between the ceramic and the composite resin increase the risk of cohesive fractures (21). For this reason, achieving the highest SBS may not be the most significant clinical factor. The clinicians should prefer ideal bonding methods that can endure masticatory and orthodontic forces during treatment and easily debonded at the end of the treatment. In this study, all surface treatment groups acquired optimum or higher mean SBS. Porcelain bracket groups showed lower mean SBS than metal bracket groups other than Nd: Yag laser group, this difference reached statistical significance only in Fs laser group ($p<0.05$; 9.68±1.95 MPa and 13.01±2.43 MPa, respectively). It was shown that ceramic brackets promote higher SBS than metal brackets (13). Differences in bonding materials/adhesives, different settings of load application, and different material preparation techniques might be the reason for variation of the results in this study.

In the literature, different ceramic materials have been subjected to surface conditioning with different laser types, and acceptable results have been reported regarding SBS of orthodontic brackets (5, 11, 12). There are no optimized laser processing parameters for each material to be tested because of unique microstructure configurations and chemical compositions of the materials (22). For this reason, we conducted a pilot study for optimum Fs laser parameters both to attain minimal ablation rate and uniform surface morphology for bonding. Laser settings of five scans, a laser pulse power of 0.05 W, and line gap of 30 µm were chosen. Using these optimized parameters, ~5 µm ablation was observed in 3D profilometer evaluation (Figure 4). We did not observe melted and scattered particles and cracks because of the Fs laser conditioning of resin nanoceramics in SEM and 3D profilometer analyses. This observation showed the notable lack of heating and shockwave effects of Fs laser on resin nanoceramic. Absence of microcracks with uniform micro and nano roughnesses on resin nanoceramic surface after Fs laser irradiation might contribute to higher SBS (Figures 2f and 3f).

Erdur et al. (5) performed *in vitro* study on feldspathic and e-Max surfaces using Ti: sapphire Fs, Nd: Yag, and Er: Yag lasers, and reported that the highest SBS was obtained with Ti: sapphire Fs laser conditioning. Akpinar et al. (23) also reported higher SBS for Ti: sapphire Fs laser on feldspathic porcelain surfaces. Aglarci et al. (24) compared SBS of extracted human premolar teeth conditioned with Ti: sapphire Fs laser and Er: Yag laser using metal brackets and reported lower SBS for Ti:sapphire Fs laser group, probably from single laser scan regime. Although using different power settings owing to material differences, our results are in line with Erdur et al. (5) and Akpinar et. al. (23)

Although some of the researchers have reported that Nd: Yag laser conditioning is an effective technique for bracket adhesion to porcelain surfaces (25, 26), there are other researchers who stated insufficent bond strengths with Nd: Yag laser (5, 12). In this study, Nd: Yag laser conditioning caused optimum SBS and lower PFI scores. Hybrid compound of organic and inorganic particles in resin nanoceramics might render it susceptible to laser penetration and responsible for causing optimum SBS values.

Cojet System uses 30-µm $Al_2O_3$ particles coated with silica for surface modification. With the aid of high-pressure deposition of these particles on the substrate surface are provided (13). A covalent bonding between silica-coated substrate and composite resin was established with the usage of Cojet System (2). In this study, silica coating followed by silane application fulfilled the required threshold. The results are in aggreement with the previous studies (2, 4, 13), but high cost is the main disadvantage of tribochemical coating. Moreover, extra precautions such as rubber dam usage and high-power suction systems are recommended to avoid soft tissue injuries and spread of particles, respectively (27).

It was found that HF acid etching was an acceptable method for ceramic surface conditioning (2). However, HF acid is responsible for dissolving the glass component of the silica-based ceramics, and there is no effect of HF acid on the high-strength materials such as zirconia and core ceramics (11, 28). In this study, HFA etching dissolved both organic and inorganic compounds of the resin nanoceramic material and created a uniform microporous surface morphology amenable to penetration of silan and adhesive resin (Figure 2c). Its surface roughness values were comparable to OPA group and lesser than Cojet and Fs laser groups (Figure 3 and Table 5). HFA proved to be an effective surface conditioning method for resin nanoceramics, but it is a highly toxic and corrosive material, so maximum precautions should be taken such as protective clothing and safety goggles to avoid skin and eye contact (29). We found that OPA-etched groups had similar SBS to those that are HFA-etched. Surface modification effect of OPA can be clearly seen on SEM images and 3D profilometer analysis (Figures 2b and 3b). The possible reason for acceptable SBS of OPA etched groups was the increased micromechanic retention because of the modification of polymer containing organic component of the resin nanoceramic. Backer et al has shown that resin composite CAD/CAM materials are susceptible to roughening in acid conditions, which differs from conventional ceramics (30). Further studies are needed to clarify the exact role of OPA on resin nanoceramics. Main advantages of both OPA and HFA conditioning to laser systems or air borne particle abrasion are their cost effectiveness and ease of application.

In this study, ARI scores did not show correlation with the bond strength. The groups with similiar SBS had different ARI scores, so one cannot define the site of bond failure with a definite threshold of shear force (2). But, mean SBS increases could imply a failure mode shift from ceramic and composite resin to composite resin and bracket interface.

All surface conditioning methods investigated in this study have sufficent SBS to withstand forces during orthodontic treatment. In fact, higher SBS exibited by Cojet and Fs laser groups showed higher PFI scores. Lawson et al (31) suggested polymer containing CAD/CAM materials might not possess high initial strength. Goujat et al (7) stated lower fracture toughness values for resin nanoceramics. These facts can elucidate high PFI scores seen in our study that resin nanoceramic could not withstand concentric high pressure during debonding. Due to high PFI scores obtained in this study, extra precautions should be taken for debonding of resin nanoceramics.

Regarding the limited amount of studies evaluating surface roughness of conditioned porcelain surfaces, Erdur et al (32) reported Fs laser treated group having the highest mean roughness value. Interestingly, using a 5% HFA just for 20 seconds on IPS e-Max surfaces, they also reported 2.21 µm mean surface roughness, which was much higher than HFA group of this study. Other than different measurement techniques and different glass components of study materials, they also did not include a "no treatment" group, making impossible to know roughness value of the test material before surface conditioning, therefore, any comparisons between the studies might be arbitrary. Çevik et al. (12) reported no significant differences among control, OPA, or HFA treated surfaces of lithium disilicate and feldspathic ceramics. In this study, mean surface roughness values of OPA and HFA were similiar and significantly higher than the control group. Conditioning protocol, material, and measurement differences could be speculated as possible causative factors. In this study, Cojet produced the highest mean surface roughness while Fs laser came behind. These values are the means of midsection measurements none of the surface conditioning groups caused ablation other than Fs laser group. If~5 µm ablation detected on border area of Fs laser group added to the calculation the highest mean surface roughness ought to be the Fs laser group (Figure 4). Surface roughness values of Nd: Yag, HFA, and OPA groups were in acceptable range. Although on µm level, roughness values of Fs laser and Cojet groups might rise concerns of patients following debonding especially for minimally prepared anterior full crown restorations and might require repairs or renewals.



## CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions can be made.

- HFA is an effective method for surface conditioning of resin nanoceramic material as stated before for other ceramic materials. OPA combined with silane application caused optimum SBS and can be used as an alternative to HFA.
- Surface conditioning with Nd: Yag laser provided optimum SBS and PFI scores for resin nanoceramic material.
- Although surface conditioning of resin nanoceramic material with Fs laser and Cojet treatment provided optimum or higher SBS, increase in ceramic fracture risk during debonding, possible aesthetic failures because of elevated micro roughness and high cost are important disadvantages of these methods. Moreover, requirement of a pilot study for optimum Fs laser dosage is another disadvantage of Fs laser usage. Clinicians planning to use Cojet or Fs laser for surface conditioning of hybrid ceramics should approach with caution and limit their usage only for specific cases, which demand higher SBS and previously informing the patient about risk of failure.

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## REFERENCES

1. Blatz MB, Sadan A, Kern M. Resin-ceramic bonding: a review of the literature. J Prosthet Dent 2003; 89: 268-74. [Crossref]
2. Karan S, Büyükyilmaz T, Toroğlu MS. Orthodontic bonding to several ceramic surfaces: are there acceptable alternatives to conventional methods? Am J Orthod Dentofac Orthop 2007; 132: 7-14. [Crossref]
3. Turk T, Sarac D, Sarac YS, Elekdag-Turk S. Effects of surface conditioning on bond strength of metal brackets to all-ceramic surfaces. Eur J Orthod 2006; 28: 450-6. [Crossref]
4. Schmage P, Nergiz I, Herrmann W, Özcan M. Influence of various surface-conditioning methods on the bond strength of metal brackets to ceramic surfaces. Am J Orthod Dentofac Orthop 2003; 123: 540-6. [Crossref]
5. Erdur EA, Basciftci FA. Effect of Ti:sapphire laser on shear bond strength of orthodontic brackets to ceramic surfaces. Lasers Surg Med 2015; 47: 512-9. [Crossref]
6. An KM Sohn DS. The effect of using laser for ceramic bracket bonding of porcelain surfaces. Korean J Orthod 2008; 38: 275-82. [Crossref]
7. Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D, et al. Mechanical properties and internal fit of 4 CAD-CAM block materials. J Prosthet Dent. 2018; 119 :384-9. [Crossref]
8. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent Mater 2013; 29: 419-26. [Crossref]
9. Ruse ND, Sadoun MJ. Resin-composite blocks for dental CAD/CAM applications. J Dent Res 2014; 93: 1232-4. [Crossref]
10. Nguyen JF, Migonney V, Ruse ND SM. Resin composite blocks via high-pressure high-temperature polymerization. Dent Mater 2012; 28: 529-34. [Crossref]
11. Cevik P, Eraslan O, Eser K, Tekeli S. Shear bond strength of ceramic brackets bonded to surface-treated feldspathic porcelain after thermocycling. Int J Artif Organs 2018; 41: 160-7. [Crossref]
12. Cevik P, Karacam N, Eraslan O, Sari Z. Effects of different surface treatments on shear bond strength between ceramic systems and metal brackets. J Adhes Sci Technol 2017; 31: 1105-15. [Crossref]
13. Elsaka SE. Influence of surface treatments on bond strength of metal and ceramic brackets to a novel CAD/CAM hybrid ceramic material. Odontology 2016; 104: 68-76. [Crossref]
14. Ozcan M. The use of chairside silica coating for different dental applications: a clinical report. J Prosthet Dent 2002; 87: 469-72. [Crossref]
15. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod Dentofac Orthop 1984; 85: 333-40. [Crossref]
16. Bourke BM, Rock WP. Factors Affecting the Shear Bond Strength of Orthodontic Brackets to Porcelain. Br J Orthod 1999; 26: 285-90. [Crossref]
17. Alessandretti R, Borba M, Benetti P, Corazza PH, Ribeiro R, Della Bona A. Reliability and mode of failure of bonded monolithic and multilayer ceramics. Dent Mater. 2017; 33: 191-7. [Crossref]
18. Della Bona A, Pecho OE, Ghinea R, Cardona JC, Pérez MM. Colour parameters and shade correspondence of CAD-CAM ceramic systems. J Dent 2015; 43: 726-34. [Crossref]
19. Sfondrini MF, Gandini P, Malfatto M, Di Corato F, Trovati F, Scribante A. Computerized casts for orthodontic purpose using powder-free intraoral scanners: accuracy, execution time, and patient feedback. Biomed Res Int 2018; 4103232. [Crossref]
20. Scribante A, Contreras-Bulnes R, Montasser MA, Vallittu PK. Orthodontics: Bracket Materials, Adhesives Systems, and Their Bond Strength. Biomed Res Int. 2016; 1329814. [Crossref]
21. Thurmond JW, Barkmeier WW, Wilwerding TM. Effect of porcelain surface treatments on bond strengths of composite resin bonded to porcelain. J Prosthet Dent 1994; 72: 355-9. [Crossref]
22. Ji L, Li L, Devlin H, Liu Z, Jiao J, Whitehead D. Ti: Sapphire femtosecond laser ablation of dental enamel, dentine, and cementum. Lasers Med Sci 2012; 27: 197-204. [Crossref]
23. Akpinar YZ, Irgin C, Yavuz T, Aslan MA, Kilic HS, Usumez A. Effect of femtosecond laser treatment on the shear bond strength of a metal bracket to prepared porcelain surface. Photomed Laser Surg 2015; 33: 206-12. [Crossref]
24. Aglarci C, Demir N, Aksakalli S, Dilber E, Sozer OA, Kilic HS. Bond strengths of brackets bonded to enamel surfaces conditioned with femtosecond and Er:YAG laser systems. Lasers Med Sci 2016; 31: 1177-83. [Crossref]
25. Hosseini MH, Sobouti F, Etemadi A, Chiniforush N, Shariati M. Shear bond strength of metal brackets to feldspathic porcelain treated by Nd:YAG laser and hydrofluoric acid. Lasers Med Sci 2015; 30: 837-41. [Crossref]
26. Poosti M, Jahanbin A, Mahdavi P, Mehrnoush S. Porcelain conditioning with Nd: YAG and Er:YAG laser for bracket bonding in orthodontics. Lasers Med Sci 2012; 27: 321-4. [Crossref]
27. Galia Reston E, Filho Calabrez S, Arossi G, Barreto Cogo R, Dos Santos Rocha C, Quadrado Closs L. Repairing ceramic restorations: final solution or alternative procedure? Oper Dent 2008; 33: 461-6. [Crossref]
28. Zhang ZC, Qian YF, Yang YM, Feng QP, Shen G. Bond strength of metal brackets bonded to a silica-based ceramic with light-cured adhesive: influence of various surface treatment methods. J Orofac Orthop 2016; 77: 366-72. [Crossref]
29. Ozcan M, Allahbeickaraghi A, Dundar M. Possible hazardous effects of hydrofluoric acid and recommendations for treatment approach: a review. Clin Oral Investig 2012; 16: 15-23. [Crossref]
30. Backer AD, Eliseu AM, Eckert GJ. Effects of simulated gastric juice on CAD/CAM resin composites-morphological and mechanical evaluations. J Prosthodont 2017; 26: 424-31. [Crossref]
31. Lawson NC, Bansal R, Burgess JO. Wear, strength, modulus and hardness of CAD/CAM restorative materials. Dent Mater 2016; 32: 275-83. [Crossref]
32. Erdur EA, Basciftci FA. Effect of ti: sapphire-femtosecond laser on the surface roughness of ceramics. Lasers Surg Med 2015; 47: 833-8. [Crossref]

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Review

# Strategies for Managing the Risk of Mucogingival Changes During Impacted Maxillary Canine Treatment

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## ABSTRACT

Gingival recession is a frequent mucogingival defect in the adult population. It affects the esthetics and is related to hypersensitivity and a high risk of periodontal attachment loss. The connection between orthodontic treatment and periodontal health has been debated for a long time. A healthy periodontium can be preserved during safe orthodontic tooth movement even in patients with poor mucogingival anatomy. This article aimed to review the strategies around managing the risks of mucogingival and apical root changes owing to maxillary canine impaction, with a special focus on gingival recession and impacted maxillary canine treatment.

Maxillary canines are the second most frequently impacted teeth after the third molars. They can be located in the labial or buccal aspect of the alveolar bone. If interceptive procedures fail, the next step is the challenging and time-consuming comprehensive orthodontic-surgical treatment. Determining the exact impacted canine location, its relation to the adjacent teeth and structures, the least invasive surgical approach, and the best path for traction are all a part of the standard diagnostic process. It has also been suggested that orthodontists should evaluate periodontal risks to achieve the best possible results. Clinical examination and cone beam computed tomography provide valuable information for the treatment plan that yields good results with a healthy periodontium.

**Keywords:** Gingival recession, impacted canine, mucogingival defect, periodontal health, periodontium

Main points:

- Awareness of periodontal risks, among many other criteria, is an important factor for a successful management of impacted maxillary teeth.
- Several factors such as the initial impacted canine position, periodontal biotype, pre-existing mucogingival changes, surgical technique, and orthodontic traction affect the periodontal status after the impacted maxillary canine treatment
- Periodontal risk assessment is an important part of the diagnostic process for many orthodontic patients, especially those treated for impacted maxillary canines.
- Clinical examination and CBCT imaging should give the orthodontist sufficient information to incorporate into the treatment planning process to achieve good and stable results accompanied by a healthy periodontium.

## INTRODUCTION

Lack of keratinized tissue and gingival recession are the two main mucogingival defect categories that should be considered when planning an orthodontic treatment. Gingival recession is a condition where the gingival margin migrates apically away from the cementoenamel junction, exposing the root surface (1). Whether localized or generalized, it is frequent in adults and tends to increase with age. Approximately 50% of people between the ages of 18 and 64 years have 1 or more gingival recession sites (2). Because an increasing proportion of practices are focusing on adult treatment, identifying gingival recession and the risks of its progression is very important. Gingival recession is clinically significant for many reasons. The presence of recession is not only esthetically unacceptable for many patients but can also be associated with hypersensitivity and potentiate the risk for further periodontal attachment loss (3).

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The etiology of recession is yet to be fully elucidated; however, evidence suggests that anatomy, physiology, and tooth position are the risk factors that play a role. The connection between orthodontic treatment and periodontal health has been debated at length and is still controversial (4). However, it has long since been recognized that safe orthodontic tooth movement is associated with mucogingival characteristics, and a healthy periodontium can be maintained during the orthodontic treatment in areas with even a minimal zone of keratinized tissue. Nevertheless, moving teeth outside of the alveolar bone housing puts them at risk for recession (5). Contemporary diagnostic tools help to identify those risks in terms of anatomy and individual patient susceptibility.

This article aimed to review the strategies for managing the risks of mucogingival changes, with a special focus on gingival recession and impacted maxillary canine treatment.

**Periodontal Risks**

Diagnosing periodontal biotypes and pre-existing mucogingival changes is the first step in the risk management of a progressing defect. Several aspects such as anatomic, physiological, and tooth position risks need to be evaluated. Successful managing of the periodontal risks during orthodontic treatment lies in a personalized assessment of these factors.



**Anatomic Risks**

Different terms have been used to describe gingival anatomy, which is determined by the underlying bone, function, tooth form, and crown height. Ochsenbein and Ross (6) were the first to use the terms "scalloped" and "flat" to classify the gingiva. These became "thin-scalloped" and "thick-flat" types and later on "periodontal biotypes" (7, 8). More terms such as periodontal morphotypes and periodontal phenotypes were coined soon after. All these terms connect bone morphotypes, shape of teeth, morphologic characteristics of the gingiva, and the periodontium (9-11).

One of the most important anatomic risk factors is the amount of the keratinized tissue. Keratinized gingiva includes free and attached gingiva and stretches between the gingival margin and the mucogingival junction (12). This distance can be measured using a periodontal probe and varies between 1 mm and 9 mm. An insufficient amount of keratinized tissue makes a patient susceptible to further recession when inflammation is present. What constitutes the "lack" of keratinized tissue is still fiercely debated. Most periodontists agree that at least 1 mm or more of the attached gingiva is essential for maintaining periodontal health in a suboptimal plaque control environment (13). According to Claffey and Shanley (14), less than 1.5 mm gingival thickness is considered a thin tissue biotype and makes a patient more susceptible to periodontal diseases, whereas thickness greater than or equal to 2 mm is considered a thick tissue biotype. It has also been shown that thin pretreatment gingival biotype and a narrow keratinized gingival width predispose an orthodontic patient to gingival recession. Current recommendations propose that we need at least 1 mm or more of the attached gingiva and at least 2 mm or more of the gingival tissue around a tooth for safe orthodontic procedures (13).

Tissue thickness is most easily assessed by placing a metal instrument, usually a periodontal probe, in the facial sulcus. The thin-scalloped periodontium that can often be found around slender triangular-shaped crowns and is usually paired with a narrow keratinized tissue width can be diagnosed easily considering the fact that the overlying gingiva is thin and clear, which allows the probe to be visible through it (11). Thickness can also be assessed by transgingival probing or ultrasonic measurement, but because it may induce discomfort, it is usually performed under local anesthesia (15).

A few more factors, such as high frenulum attachment and a shallow vestibule, might also contribute to potential damage during the orthodontic treatment (13).

**Physiological Risks**

Appropriate oral hygiene and professional periodontal maintenance are recognized methods that help keep the sites with anatomic susceptibility to progressing mucogingival defects healthy (16). Such sites are usually kept free from inflammation prior to the orthodontic treatment. If persistent bleeding, swelling, redness, or other signs of inflammation are detected or brought up by the patient during the orthodontic treatment, personalized risk modulation would drive an orthodontist to intervene.

Ironically, a high proportion of individuals with recessions has been reported in populations with high standards of oral hygiene. This supports the assertion that improper brushing and/or aggressive cleaning techniques, such as horizontal scrubbing, excessive force, or hard bristle brushes, may contribute to mucogingival pathology. This offers another opportunity for the orthodontist to manage the risk of these defects by emphasizing on proper oral hygiene techniques.

**Tooth Position/Orthodontic Treatment Risks**

Orthodontic tooth movement using optimal forces causes adequate periodontal ligament and alveolar bone response. However, recession can be initiated or progressed depending on the direction of movement. Moving teeth buccally is usually associated with gingival recession owing to thin gingiva and alveolar housing. Buccal tooth movement, especially using heavy forces, might take teeth outside the alveolar bone and result in reduced bony support and formation of dehiscences and fenestrations, causing the gingiva to migrate apically and leave an exposed root surface (17, 18). Because this process takes time, recession may not be evident until the postorthodontic retention phase, which has been reported in the literature (19).

**Impacted Maxillary Canines**

The case of impacted maxillary canine exposure is an interesting example of tooth position–related orthodontic intervention. The prevalence of maxillary canine impactions in the general population varies between 0.9% and 2.2% but has been reported to be much higher among orthodontic patients (20, 21). The location is most frequently palatal but can also be labial and intra-alveolar (20, 22). Considering the significant esthetic and functional role of these teeth, it is clear that facilitating their eruption is an important part of the orthodontic practice.

Different preventive or interceptive procedures have been suggested for patients between the ages of 10 and 13 years (23, 24). If these procedures fail or the patient is not evaluated by an orthodontist at an early age, comprehensive orthodontic-surgical treatment should be considered. Surgical exposure and orthodontic alignment of an impacted maxillary canine is a very challenging, time-consuming, and expensive procedure. Treatment difficulty, success rate, duration and necessity, as well as the patient's motivation and expected compliance are some of the most important factors that need to be considered before defining a treatment plan. Determining the precise position of the impacted canine, its relation to the adjacent anatomical structures, the best and the most predictable path for orthodontic traction, and the least invasive surgical approach are some of the essential data needed for designing a solid treatment plan (25, 26).

By treating impacted teeth, an orthodontist enhances the esthetics and function of the patient without the added trauma of tooth replacement with a dental implant. Nevertheless, there is a wide range of positional and biomechanical issues that can end with gingival margin disharmony. Depending on the location of the tooth, surrounding soft tissue features, and periodontal implications, different surgical approaches and subsequent orthodontic traction are suggested.

**Labially Impacted Maxillary Canines**

Labial maxillary canine impactions are less frequent but more challenging in terms of periodontal health. These teeth are covered by a thin mucosa indicative of thin alveolar plate susceptible to dehiscence and recession. There is also insufficient labial bone to move the canine over the adjacent tooth (27). Excisional uncovering, apically positioned flap, or closed eruption technique can be used. Excisional uncovering is suggested when the impacted canine crown tip is positioned coronal to the cementoenamel junction of the adjacent teeth and there is a wide zone of attached gingiva. When the tooth is positioned below the mucogingival junction and the attached gingiva is insufficient, use of apically positioned flap is recommended. If the tooth is located above the mucogingival junction, closed eruption technique is the best option. Orthodontic traction should mimic physiological eruption and bring the tooth to the middle of the alveolar ridge. The type of orthodontic mechanics will depend on the crown position and its relation to the adjacent teeth and structures (28, 29).

**Palatally Impacted Maxillary Canines**

Palatal canine impactions are more prevalent. Kokich and Mathews (29) split them in two groups: simple and complex, depending on the impaction severity. Becker's classification is more compound, consists of six groups, and based on canine proximity to the line of the arch and vertical crown position in relation to the occlusal plane (28). Kokich and Mathews suggested early uncovering and "autonomous" eruption method for simple palatal impactions (30, 31). Among other benefits, they stressed on better functioning periodontal ligament and reduced risk from root resorption (30). Complex palatal impactions are commonly treated by the closed eruption technique. Becker and Zilberman (32) suggested moving the canine lingually away from the roots of the adjacent teeth (Figure 1) and moving it to its proper position only after the crown emerges on the palate. However, many clinicians pull the canine buccally toward the alveolar ridge right away, which can cause different adverse effects (Figures 2 and 3) (28, 29, 32, 33).

**Imaging**

In order to achieve a predictable and successful outcome, we need to obtain precise information. The first diagnostic step is the clinical examination during which we might detect malocclusion, prolonged retention of deciduous teeth, delayed eruption of permanent teeth, presence or absence of bulges in the area of unerupted teeth, and other concerns. (21, 34). After the initial examination, orthodontists usually resort to radiography—the first one is typically the panoramic radiograph—to establish, among other things, whether the canine is present and where it is located. Using this two-dimensional (2D) diagnostic tool, we can determine the general location of the impacted canine. By means of the magnification technique described and validated by Chaushu et al. (35), the labiolingual position of the canine can be assessed, and with the help of the methodologies described by Dausch-Neumann (36) and Ericson and Kurol (37, 38), we can evaluate the canine position, treatment difficulty, and success rate. The radiographic parameters described by Ericson and Kurol (37) can also be used to predict spontaneous eruption probability, need for interceptive treatment, treatment duration and difficulty, and chairside time (39, 40). Attempts have been made to use the same parameters to predict periodontal response; however, they did not prove to be valid predictors of the periodontal status at the end of the treatment, (41) with the exception of location of the palatally impacted canine crown tip in relation to the long axes of incisors and first premolars (42). It has been proposed that the closer the canine tip is to the incisor midline, higher is the probability for periodontal damage at the end of the treatment.

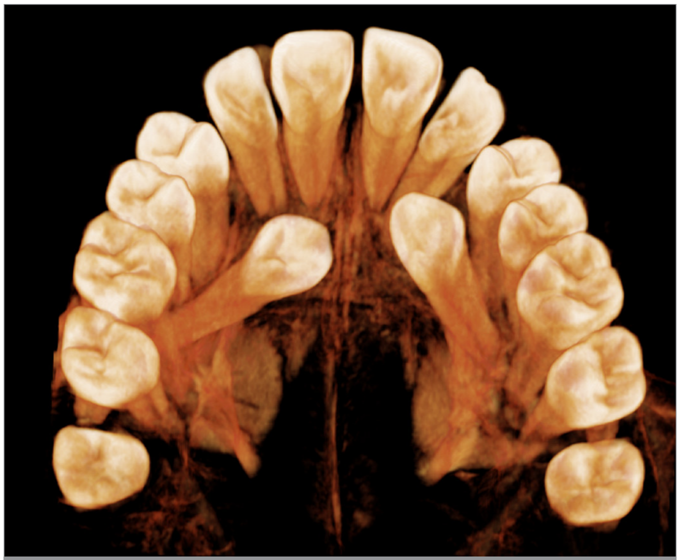

**Figure 1.** Both impacted canines are moved lingually away from the roots of the adjacent teeth in order to avoid root resorption.

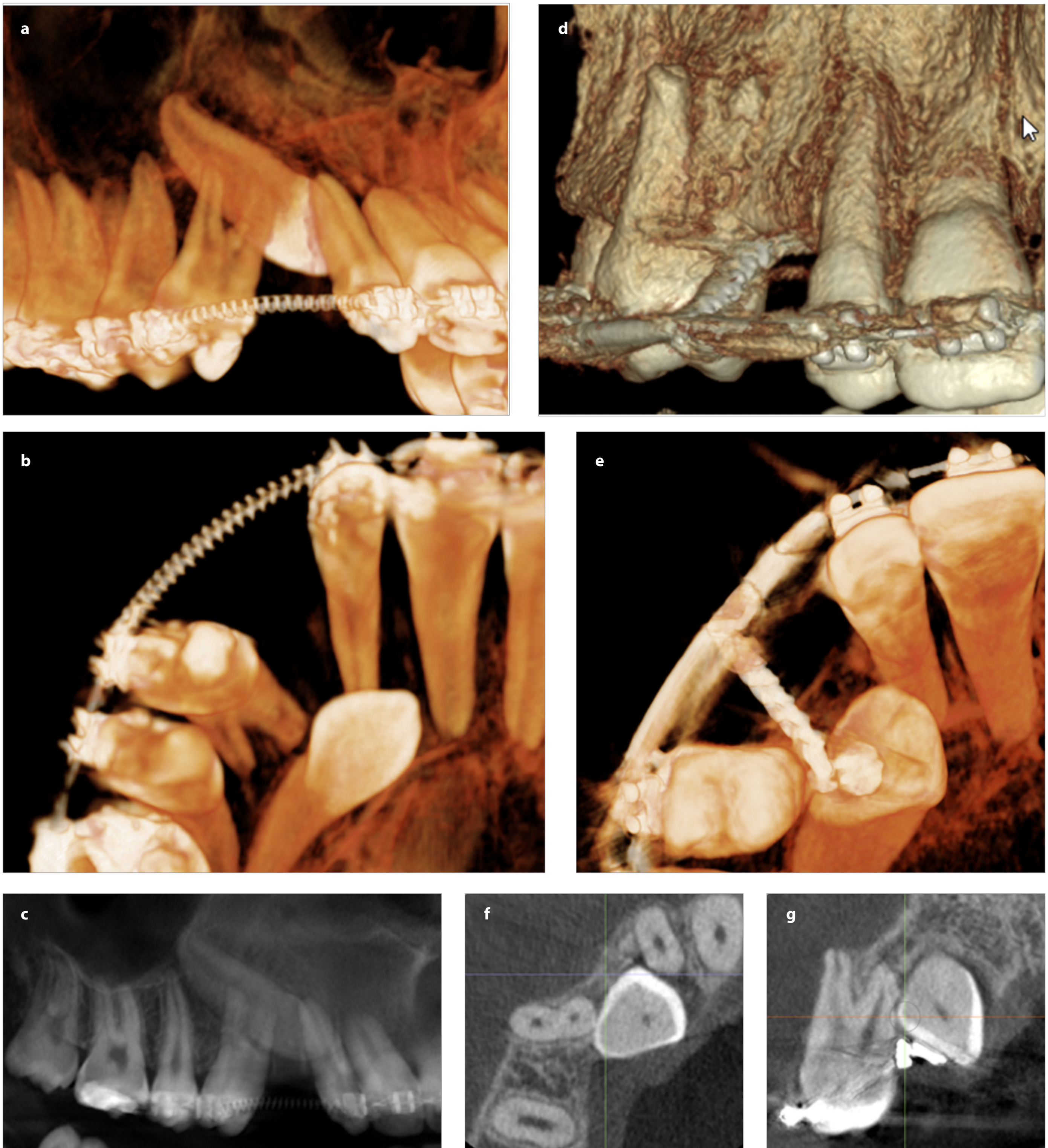


**Figure 2. a-g.** Inadequate orthodontic traction. Cone beam computer tomography (CBCT) images taken before orthodontic traction (T1) and after nine months of orthodontic traction when the patient was referred (T2), (a) and (b) 3D reconstruction at T1, (c) part of the CBCT panoramic reconstruction at T1, (d) and (e) 3D reconstruction at T2, (f) axial slice at T2, (g) coronal slice at T2.

For those orthodontists using 2D radiography exclusively, the next step would be taking two periapical radiographs or a combination of a periapical and an occlusal radiograph for the horizontal or vertical parallax method, as well as a lateral and posteroanterior cephalogram (43-45). This means that at least three, sometimes even four or more, 2D radiographs would be needed, which increases the radiation exposure for the patient (46). Moreover, it has been shown that predictions based on angular and linear parameters are not reliable enough because of the limitations of 2D images (28). The superimposition of anatomical structures, geometric distortion, and differential magnification on 2D diagnostic images can lead to misinterpretation of data and consequently sabotage the treatment plan.

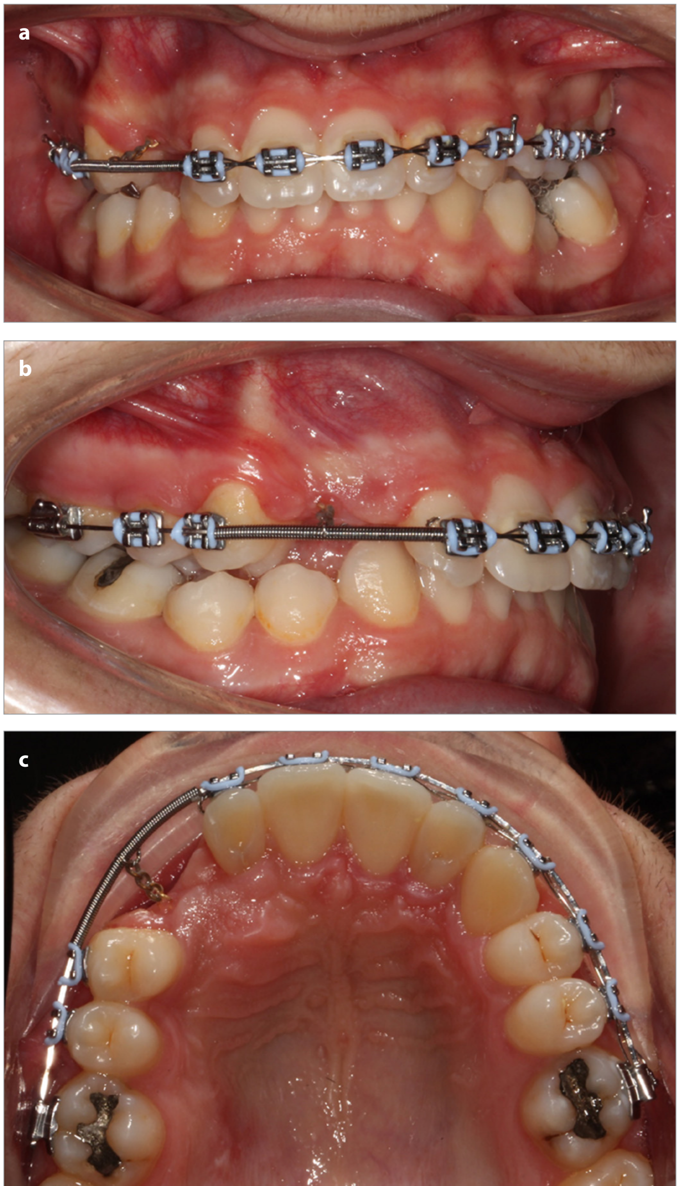


**Figure 3. a-c.** Intraoral images of the patient from Figure 2; (a) frontal, (b) right lateral, (c) occlusal.

Therefore, we need three-dimensional (3D) data; hence, an increasing number of orthodontists are resorting to cone beam computed tomography (CBCT) for diagnosing impacted teeth (47). Using CBCT, we can define the exact location of the impacted canine and its relation to the surrounding teeth and other anatomical structures and detect the possible resorptions. Because buccolingual position of teeth has a profound effect on gingival tissue dimensional variation, risk of mucogingival defects can also be modulated through imaging to identify not only the current bone morphology but also the morphology likely to exist after the treatment.

The 3D data obtained help us make the most favorable treatment plan for both the surgical approach and orthodontic traction, which may be different from the one based on 2D data only. Furthermore, CBCT images display no distortion and less scattering around orthodontic brackets, bands, archwires, and metallic restorations, which adds to the diagnostic quality (Figure 2). In conclusion, CBCT-based diagnostics can help us achieve better results in lesser time, especially when dealing with more complex canine impactions (25).

**Impacted Maxillary Canine Severity Classification**

The methodology described in the 1980s by Ericson and Kurol (37) was the most widespread classification system for palatally impacted maxillary canines before the introduction of CBCT to everyday orthodontic practice. It allowed the clinicians to determine the position of the impacted tooth and evaluate treatment difficulty and success rate. The parameters were later used to predict spontaneous eruption probability, interceptive treatment need, comprehensive treatment duration, difficulty, and chairside time (26).

Owing to the widespread use of CBCT, several novel methodologies have been developed for impacted maxillary canine diagnosis and classification, the first one being the Kau – Pan – Gallerano (KPG) index (48). The KPG index helps the orthodontists define the treatment complexity (easy, moderate, difficult, and extremely difficult). Complexity is determined according to the score calculated from values obtained in the X-, Y-, and Z-axes. On the X-axis of the CBCT panoramic view, the mesiodistal position of the canine crown and root relative to the adjacent teeth is determined, and on the Y-axis, vertical cusp and root tip position in relation to the developmental norm is evaluated. The Z-axis is found on the axial slices where the perpendicular distance from the cusp and root tip to the occlusal line is measured in 2 mm increments (49).



A few years later, Naoumova et al. (50) described and validated a method for assessing the precise position of palatally impacted maxillary canines. They proposed measuring the mesial inclination and cusp to midline distance in coronal view, sagittal angle and vertical position in sagittal view, and cusp and root tip distance to the dental arch in axial view (Figure 4).

Finally, Zeno and Ghafari (51) introduced a new assessment method based on the projected treatment outcome. It was based on the idea that personalization through evaluation relative to the virtual posttreatment outcome would better reflect the impaction severity.

**Incisor Root Resorption Associated with Impacted Canines**

Incisor root resorption can be caused by an impacted canine (Figure 5) or can be a sequela of the impacted canine treatment. When using 2D radiographs (panoramic, periapical, and cephalograms) to detect external root resorption, we can only identify root shortening and mesial or distal surface resorption (52). Furthermore, 2D radiographs underestimate or overestimate the amount of resorption and are not reliable for detecting the early stages of resorption (53). CBCT allows us to look at the roots in all the three planes of space and in much more detail. We can obtain high-precision measurements and easily detect even the early stages of root resorption (54). We should also note that false positive results are found in less than 10% of cases with no lesions using CBCT, as opposed to 20% false positives found

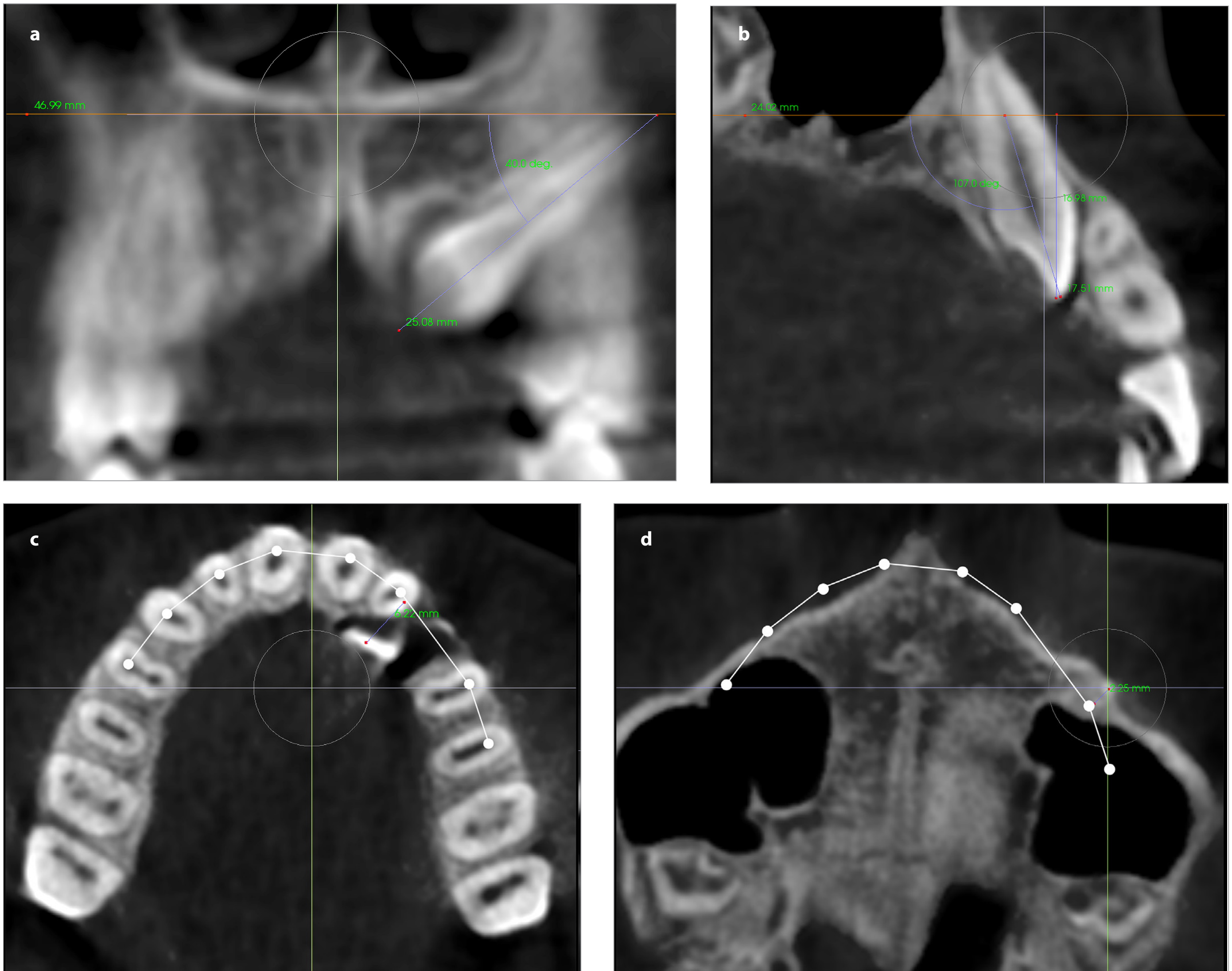


**Figure 4. a-d.** (a) Mesioangular angle of palatally displaced canine with reference to the palatal plane measured on coronal view, (b) sagittal angle and vertical position measured onsagittal view, (c) distance measured from the canine cusp tip to the dental arch on axial view, and (d) distance from root apex of the canine to the dental arch on axial view.



using 2D modalities (54). Better information about root resorption may be critical in changing the extraction treatment plan and eventually extracting a resorbed lateral incisor instead of a healthy premolar (55).

### Periodontal Response

Several factors such as the initial impacted canine position, periodontal biotype, pre-existing mucogingival changes, surgical technique, and orthodontic traction affect the periodontal status after the impacted maxillary canine treatment (42, 56).

Periodontal risk assessment is an important step that needs to be incorporated into the diagnostic and treatment planning processes for further treatment quality improvement. Through the clinical examination (periodontal probing, transgingival probing, and ultrasonic measurement), we can determine the periodontal biotype, keratinized tissue, and attached gingiva measurements. If there is a CBCT image available, we should use it to take a closer look into the bone morphology and the hard and soft tissue thickness (57). By determining these parameters, we can further evaluate the risks because it has been shown that there is a significant correlation between the periodontal biotype and the labial plate thickness, alveolar crest position, keratinized tissue width, gingival architecture, and probe visibility (17).

### Initial Impacted Canine Position

Few studies have compared the periodontal status at the end of labial and palatal impaction treatments; hence, it is still not clear which impacted canine position is more favorable in terms of the end of the treatment periodontal status. Bollero et al. (58) found greater probing pocket depth after palatal impaction treatment than after labial impaction treatment, but the results lacked clinical significance. Comparing palatally and labially impacted canines to untreated contralaterals, Evren et al. (59) found worse periodontal status around the treated canines; however, labially impacted canines presented with a lower electric pulp testing score and higher bone levels compared with those of the palatally impacted canines. Several authors compared palatally

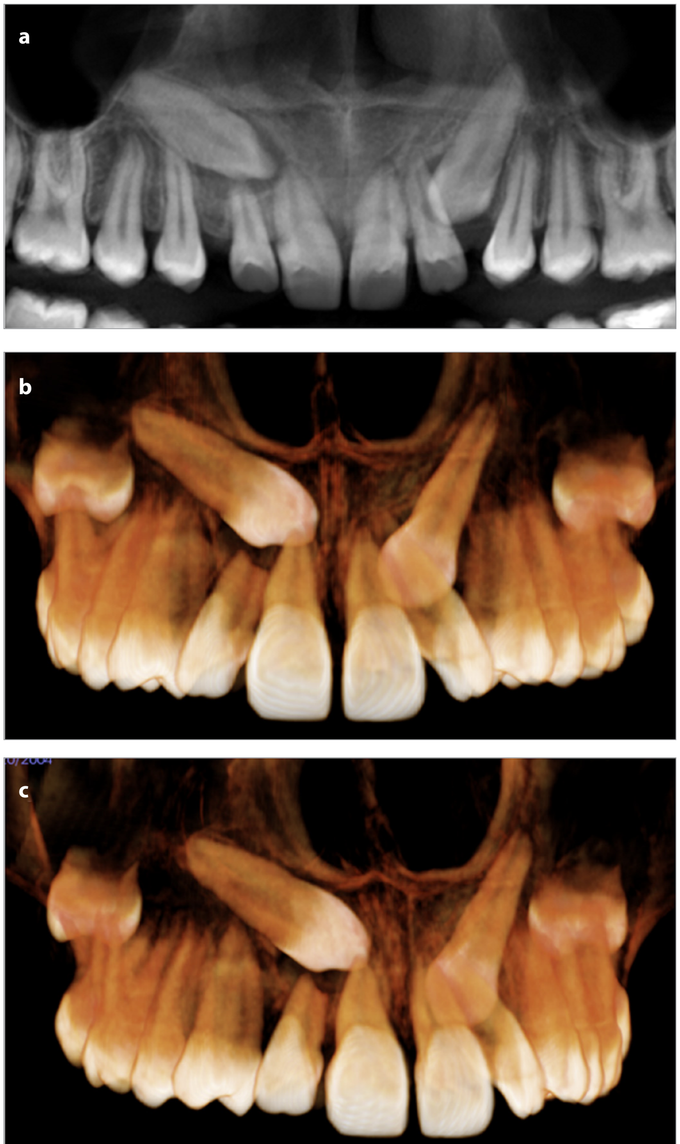


**Figure 5. a-c.** Patient with lateral incisor resorption before orthodontic treatment. (a) Part of the CBCT panoramic reconstruction, and (b, c) 3D reconstruction.

impacted canines to untreated contralaterals and reached different conclusions. Burden et al. (60) found worse periodontal status around the treated canines, whereas Hansson and Rindler (61) noted good gingival and periodontal status with slightly increased pocket depth and lower marginal bone level. Zasciurinskiene et al. (62) found no significant differences in gingival recessions between the treated canines and controls and concluded that the posttreatment periodontal conditions of the treated canines and adjacent teeth depended on the initial vertical and horizontal impacted canine positions.

### Type of Surgery

Several studies have investigated esthetic and periodontal outcomes after different surgical exposure techniques of labially impacted canines, unfortunately, with inconsistent results (41, 56, 63). A systematic review comparing different surgical uncovering procedures found the apically positioned flap to be superior to excisional uncovering, with periodontal outcomes comparable with untreated teeth (64). Some authors found that closed eruption technique resulted in better esthetics and periodontal health, (56, 63) whereas others came to opposing conclusions (65). These inconsistences are probably due to different methodologies used for evaluating periodontal health as well as the fact that orthodontic traction and the initial tooth position play an important role in achieving the best possible results in terms of stability and periodontal health (29, 66).

When it comes to palatally impacted canines, a Cochrane systematic review analyzed the outcome differences between the open and closed eruption techniques in terms of success and other clinical and patient-reported outcomes (67). The periodontal health–related results they looked into were probing depth, bleeding on probing, clinical attachment level, crestal bone levels, gingival recession, and mid-buccal and mid-palatal recession. They found no differences between the two techniques.

This has also been confirmed by a recent systematic review and meta-analysis that compared the open and the closed techniques for both labially and palatally impacted canines and concluded there were no differences in periodontal health and esthetics outcomes (68).

### Orthodontic Tooth Movement and Attachment Position

Tipping teeth orthodontically is usually linked to a delayed movement of the gingiva in relation to the tooth. This delay, together with the tension from the gingival fibers, could be a factor in the inflammation mechanism in patients treated by combined orthodontic-surgical approach (69). Placing the orthodontic traction attachment on the palatal side may cause the canine to erupt in a rotated position, and derotating it could cause increased probing depth (70).

### Removed Bone Volume

Extensive bone removal to expose the crown and remove obstacles in order to facilitate easier tooth movement was common in the early days of impacted canine treatment. However, a study conducted in the 1980s showed that if more bone is removed during the exposure, the bone loss would be greater at the end of the treatment (71). Therefore, a recommendation was made that extensive bone removal that could involve the cementoenamel junction should be avoided (72).

### Radiation Exposure

Radiation exposure when using CBCT is certainly higher than that in 2D radiography; therefore, we need to consider the risk-benefit ratio when deciding about the diagnostic radiography. This is not an easy task, considering that the differences in radiation doses still vary significantly among different CBCT machines. Effective radiation doses of a full scan with a large field of view (FOV) (>15 cm) CBCT scanner range between 52 mSv and 1073 mSv, whereas the effective doses of panoramic radiographs vary between 6 mSv and 50 mSv and those of lateral cephalograms vary between 2 mSv and 10 mSv (73). Bearing in mind that most patients with impacted canines are children in their main growth period, the higher cancer risk from radiation makes it a critical concern. Thus, it would be advisable to use the low-dose CBCT protocols available for children and implement not just the "as low as reasonably achievable" (74) but also the as low as diagnostically acceptable standard (75).

Radiation dose of the CBCT unit can be reduced through beam collimation, FOV-region of interest (ROI) coordination, mA and kVp resetting, exposure time and dose reduction, as well as using protective shielding (lead torso aprons and thyroid shields) (74, 76). Concerns have been raised that diagnostic data could be lost due to inadequate image quality of low-radiation settings (77); however, it has been shown that adequate image quality can be maintained with reduced doses of radiation (75).

CBCT scanning is considered justified if the additional information affects the treatment plan and outcome (76). The general consensus seems to be that the benefits outweigh the risks of impacted canine diagnostics, especially because of better treatment efficiency and results (78). However, even when dealing with adult patients, it is recommended to use the FOV size suitable for the ROI, as well as lower resolution settings (79).



## CONCLUSION

Periodontal risk assessment is an important part of the diagnostic process for many orthodontic patients, especially those treated for impacted maxillary canines. Clinical examination and CBCT imaging should give the orthodontist sufficient information to incorporate into the treatment planning process in order to achieve good and stable results accompanied by a healthy periodontium.

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## REFERENCES

1. Pini Prato G. Mucogingival deformities. Ann Periodontol 1999; 4: 98-101. [Crossref]
2. Kassab MM, Cohen RE. The etiology and prevalence of gingival recession. J Am Dent Assoc 2003; 134 :220-5. [Crossref]
3. Senna P, Del Bel Cury A, Rosing C. Non-carious cervical lesions and occlusion: a systematic review of clinical studies. J Oral Rehabil. 2012; 39: 450-62. [Crossref]
4. Bollen AM, Cunha-Cruz J, Bakko DW, Huang GJ, Hujoel PP. The effects of orthodontic therapy on periodontal health: a systematic review of controlled evidence. J Am Dent Assoc 2008; 139: 413-22. [Crossref]
5. Wennstrom JL. Mucogingival considerations in orthodontic treatment. Semin Orthod 1996; 2: 46-54. [Crossref]
6. Ochsenbein C, Ross S. A reevaluation of osseous surgery. Dent Clin North Am 1969; 13: 87-102.
7. Weisgold AS. Contours of the full crown restoration. Alpha Omegan 1977; 70: 77-89.
8. Seibert JL. Esthetics and periodontal therapy. Textbook of Clinical Periodontology. 2nd ed. Copenhagen, Denmark: Munksgaard; 1989. p. 477-514.
9. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. J Clin Periodontol 1993; 20: 570-7. [Crossref]
10. Muller HP, Eger T. Gingival phenotypes in young male adults. J Clin Periodontol 1997; 24: 65-71. [Crossref]
11. Zweers J, Thomas RZ, Slot DE, Weisgold AS, Van der Weijden FG. Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. J Clin Periodontol 2014; 41: 958-71. [Crossref]
12. Orban B. Clinical and histologic study of the surface characteristics of the gingiva. Oral Surg Oral Med Oral Pathol 1948; 1: 827-41. [Crossref]
13. Kim DM, Neiva R. Periodontal soft tissue non-root coverage procedures: a systematic review from the AAP Regeneration Workshop. J Periodontol 2015; 86(2 Suppl): S56-72. [Crossref]
14. Claffey N, Shanley D. Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. J Clin Periodontol 1986; 13: 654-7. [Crossref]
15. Ronay V, Sahrmann P, Bindl A, Attin T, Schmidlin PR. Current status and perspectives of mucogingival soft tissue measurement methods. J Esthet Restor Dent 2011; 23: 146-56. [Crossref]
16. Scheyer ET, Sanz M, Dibart S, Greenwell H, John V, Kim DM, et al. Periodontal soft tissue non-root coverage procedures: a consensus report from the AAP Regeneration Workshop. J Periodontol 2015; 86(2 Suppl): S73-6. [Crossref]
17. Cook DR, Mealey BL, Verrett RG, Mills MP, Noujeim ME, Lasho DJ, et al. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. Int J Periodontics Restorative Dent 2011; 31: 345-54.
18. Zachrisson BU, Alnaes L. Periodontal condition in orthodontically treated and untreated individuals. II. Alveolar bone loss: radiographic findings. Angle Orthod 1974; 44: 48-55.
19. Renkema AM, Fudalej PS, Renkema AA, Abbas F, Bronkhorst E, Katsaros C. Gingival labial recessions in orthodontically treated and untreated individuals: a case - control study. J Clin Periodontol 2013; 40: 631-7. [Crossref]
20. Thilander B, Myrberg N. The prevalence of malocclusion in Swedish schoolchildren. Scand J Dent Res 1973; 810: 12-20. [Crossref]
21. Bishara SE. Clinical management of impacted maxillary canines. Semin Orthod 1998; 4: 87-98. [Crossref]
22. Ericson S, Kurol J. Resorption of incisors after ectopic eruption of maxillary canines: a CT study. Angle Orthod 2000; 70: 415-23.
23. Armi P, Cozza P, Baccetti T. Effect of RME and headgear treatment on the eruption of palatally displaced canines: a randomized clinical study. Angle Orthod 2011; 81: 370-4. [Crossref]
24. Baccetti T, Sigler LM, McNamara JA, Jr. An RCT on treatment of palatally displaced canines with RME and/or a transpalatal arch. Eur J Orthod 2011; 33: 601-7. [Crossref]
25. Schubert M, Proff P, Kirschneck C. Improved eruption path quantification and treatment time prognosis in alignment of impacted maxillary canines using CBCT imaging. Eur J Orthod 2018; 40: 597-607. [Crossref]
26. Zuccati G, Ghobadlu J, Nieri M, Clauser C. Factors associated with the duration of forced eruption of impacted maxillary canines: a retrospective study. Am J Orthod Dentofacial Orthop 2006; 130: 349-56. [Crossref]

27. Hwang S, Choi YJ, Chung CJ, Kim KH. Long-term survival of retained deciduous mandibular second molars and maxillary canine incorporated into final occlusion. Korean J Orthod 2017; 47: 323-33. [Crossref]
28. Becker A. Orthodontic Treatment of Impacted Teeth. 3rd ed: Wiley-Blackwell; 2012. [Crossref]
29. Kokich VG, Mathews DP. Orthodontic and surgical management of impacted teeth. Quintessence Publishing Company USA: Incorporated; 2014.
30. Mathews DP, Kokich VG. Palatally impacted canines: the case for preorthodontic uncovering and autonomous eruption. Am J Orthod Dentofacial Orthop 2013; 143: 450-8. [Crossref]
31. Kokich VG. Preorthodontic uncovering and autonomous eruption of palatally impacted maxillary canines. Semin Orthod 2010: 16; 205-11. [Crossref]
32. Becker A, Zilberman Y. The palatally impacted canine: a new approach to treatment. Am J Orthod 1978; 74: 422-9. [Crossref]
33. Kokich VG. Surgical and orthodontic management of impacted maxillary canines. Am J Orthod Dentofacial Orthop 2004; 126: 278-83. [Crossref]
34. Bishara SE, Ortho D. Impacted maxillary canines: a review. Am J Orthod Dentofacial Orthop 1992; 101: 159-71. [Crossref]
35. Chaushu S, Chaushu G, Becker A. Reliability of a method for the localization of displaced maxillary canines using a single panoramic radiograph. Clin Orthod Res 1999; 2: 194-9. [Crossref]
36. Dausch-Neumann D. The Eruption Path of Permanent Cuspids. Fortschr Kieferorthop [Article in German] 1970; 31: 9-16. [Crossref]
37. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988; 10: 283-95. [Crossref]
38. Ericson S, Kurol J. Resorption of maxillary lateral incisors caused by ectopic eruption of the canines. A clinical and radiographic analysis of predisposing factors. Am J Orthod Dentofacial Orthop 1988; 94: 503-13. [Crossref]
39. Leonardi M, Armi P, Franchi L, Baccetti T. Two interceptive approaches to palatally displaced canines: a prospective longitudinal study. Angle Orthod 2004; 74: 581-6.
40. Stewart JA, Heo G, Glover KE, Williamson PC, Lam EW, Major PW. Factors that relate to treatment duration for patients with palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2001; 119: 216-25. [Crossref]
41. Crescini A, Nieri M, Buti J, Baccetti T, Pini Prato GP. Orthodontic and periodontal outcomes of treated impacted maxillary canines. Angle Orthod 2007; 77: 571-7. [Crossref]
42. Caprioglio A, Comaglio I, Siani L, Fastuca R. Effects of impaction severity of treated palatally displaced canines on periodontal outcomes: a retrospective study. Prog Orthod 2019; 20: 5. [Crossref]
43. Clark CA. A Method of ascertaining the Relative Position of Unerupted Teeth by means of Film Radiographs. Proc R Soc Med 1910; 3(Odontol Sect): 87-90. [Crossref]
44. Keur JJ. Radiographic localization techniques. Aust Dent J 1986; 31: 86-90. [Crossref]
45. Kumar S, Mehrotra P, Bhagchandani J, Singh A, Garg A, Kumar S, et al. Localization of impacted canines. J Clin Diagn Res 2015; 9: ZE11. [Crossref]
46. Southall PJ, Gravely JF. Vertical parallax radiology to localize an object in the anterior part of the maxilla. Br J Orthod 1989; 16: 79-83. [Crossref]
47. Smith BR, Park JH, Cederberg RA. An evaluation of cone-beam computed tomography use in postgraduate orthodontic programs in the United States and Canada. J Dent Educ 2011; 75: 98-106.
48. Kau CH, Pan P, Gallerano RL, English JD. A novel 3D classification system for canine impactions-the KPG index. Int J Med Robot 2009; 5: 291-6. [Crossref]
49. Kau CH, Lee JJ, Souccar NM. The validation of a novel index assessing canine impactions. Eur J Dent 2013; 7: 399-404. [Crossref]
50. Naoumova J, Kjellberg H, Palm R. Cone-beam computed tomography for assessment of palatal displaced canine position: a methodological study. Angle Orthod. 2014; 84: 459-66. [Crossref]
51. Zeno KG, Ghafari JG. Palatally impacted canines: A new 3-dimensional assessment of severity based on treatment objective. Am J Orthod Dentofacial Orthop 2018; 153: 387-95. [Crossref]
52. Chan EK, Darendeliler MA. Exploring the third dimension in root resorption. Orthod Craniofac Res 2004; 7: 64-70. [Crossref]
53. Apajalahti S, Peltola JS. Apical root resorption after orthodontic treatment - a retrospective study. Eur J Orthod 2007; 29: 408-12. [Crossref]
54. Creanga AG, Geha H, Sankar V, Teixeira FB, McMahan CA, Noujeim M. Accuracy of digital periapical radiography and cone-beam computed tomography in detecting external root resorption. Imaging Sci Dent 2015; 45: 153-8. [Crossref]
55. Kapila SD, Nervina JM. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015; 44: 20140282. [Crossref]
56. Lee JY, Choi YJ, Choi SH, Chung CJ, Yu HS, Kim KH. Labially impacted maxillary canines after the closed eruption technique and orthodontic traction: A split-mouth comparison of periodontal recession. Journal of periodontology. 2019; 90: 35-43. [Crossref]
57. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJ, Wang HL. Tissue biotype and its relation to the underlying bone morphology. J Periodontol 2010; 81: 569-74. [Crossref]
58. Bollero P, Danesi C, Ricchiuti MR, Milazzo A, Mampieri G, Agrestini C, et al. Long-term periodontal status of palatally and buccally impacted canines after closed surgical-orthodontic approach. Oral Implantol 2017; 10: 162-71. [Crossref]
59. Evren AD, Nevzatoglu S, Arun T, Acar A. Periodontal status of ectopic canines after orthodontic treatment. Angle Orthod 2014; 84: 18-23. [Crossref]
60. Burden DJ, Mullally BH, Robinson SN. Palatally ectopic canines: closed eruption versus open eruption. Am J Orthod Dentofacial Orthop 1999; 115: 640-4. [Crossref]
61. Hansson C, Rindler A. Periodontal conditions following surgical and orthodontic treatment of palatally impacted maxillary canines-a follow-up study. Angle Orthod 1998; 68: 167-72.
62. Zasciurinskiene E, Bjerklin K, Smailiene D, Sidlauskas A, Puisys A. Initial vertical and horizontal position of palatally impacted maxillary canine and effect on periodontal status following surgical-orthodontic treatment. Angle Orthod 2008; 78: 275-80. [Crossref]
63. Crescini A, Clauser C, Giorgetti R, Cortellini P, Pini Prato GP. Tunnel traction of infraosseous impacted maxillary canines. A three-year periodontal follow-up. Am J Orthod Dentofacial Orthop 1994; 105: 61-72. [Crossref]
64. Incerti-Parenti S, Checchi V, Ippolito DR, Gracco A, Alessandri-Bonetti G. Periodontal status after surgical-orthodontic treatment of labially impacted canines with different surgical techniques: A systematic review. Am J Orthod Dentofacial Orthop 2016; 149: 463-72. [Crossref]
65. Vanarsdall RL. Efficient management of unerupted teeth: A time-tested treatment modality. Semin Orthod 2010; 16: 212-21. [Crossref]
66. Kokich V, Mathews, DA. Impacted teeth: Orthodontic and surgical considerations. In: JA McNamara J, editor. Orthodontics and Den-

tofacial Orthopedics. Ann Arbor, Michigan: Needham Press, Inc. ; 2001. p. 395-422.

67. Parkin N, Benson PE, Thind B, Shah A, Khalil I, Ghafoor S. Open versus closed surgical exposure of canine teeth that are displaced in the roof of the mouth. Cochrane Database Syst 2017; 8: Cd006966. [Crossref]
68. Cassina C, Papageorgiou SN, Eliades T. Open versus closed surgical exposure for permanent impacted canines: a systematic review and meta-analyses. Eur J Orthod 2018; 40: 1-10. [Crossref]
69. Boyd RL. Clinical assessment of injuries in orthodontic movement of impacted teeth. II. Surgical recommendations. Am J Orthod 1984; 86: 407-18. [Crossref]
70. Parkin NA, Milner RS, Deery C, Tinsley D, Smith AM, Germain P, et al. Periodontal health of palatally displaced canines treated with open or closed surgical technique: a multicenter, randomized controlled trial. Am J Orthod Dentofacial Orthop 2013; 144: 176-84. [Crossref]
71. McDonald F, Yap WL. The surgical exposure and application of direct traction of unerupted teeth. Am J Orthod 1986; 89: 331-40. [Crossref]
72. Kohavi D, Becker A, Zilberman Y. Surgical exposure, orthodontic movement, and final tooth position as factors in periodontal breakdown of treated palatally impacted canines. Am J Orthod 1984; 85: 72-7. [Crossref]
73. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. [corrected]. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2013; 116: 238-57. [Crossref]
74. Palomo JM, Rao PS, Hans MG. Influence of CBCT exposure conditions on radiation dose. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105: 773-82. [Crossref]
75. Hidalgo Rivas JA, Horner K, Thiruvenkatachari B, Davies J, Theodorakou C. Development of a low-dose protocol for cone beam CT examinations of the anterior maxilla in children. Br J Radiol 2015; 88(1054): 20150559. [Crossref]
76. Signorelli L, Patcas R, Peltomaki T, Schatzle M. Radiation dose of cone-beam computed tomography compared to conventional radiographs in orthodontics. J Orofac Orthop 2016; 77: 9-15. [Crossref]
77. Cohen MD. Pediatric CT radiation dose: how low can you go? AJR Am J Roentgenol 2009; 192: 1292-303. [Crossref]
78. Hodges RJ, Atchison KA, White SC. Impact of cone-beam computed tomography on orthodontic diagnosis and treatment planning. Am J Orthod Dentofacial Orthop 2013; 143: 665-74. [Crossref]
79. Eslami E, Barkhordar H, Abramovitch K, Kim J, Masoud MI. Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: A systematic review of comparative studies. Am J Orthod Dentofacial Orthop 2017; 151: 248-58. [Crossref]

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Review

# Use of Laser Systems in Orthodontics

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## ABSTRACT

Laser systems have been used in the practice of dentistry for >35 years. Laser systems have so many advantages, such as increase patient cooperation, reduce the duration of treatment time, and help the orthodontists to enhance the design of a patient's smile to improve treatment efficacy, and the success of orthodontic treatments can also be improved by diminishing the orthodontic pain and the discomfort of the patients. Laser systems also have some disadvantages, such as cost, large space requirements for some types, and high-risk potential for physician and patient if not used at the appropriate wavelength and power density, that is why before incorporating lasers into clinical practice, the physician must fully understand the basic science, safety protocol, and risks associated with them. Lasers have many applications in orthodontics, including accelerating tooth movement, bonding and debonding processes, pain reduction, bone regeneration, etching procedures, increase mini-implant stability, soft tissue procedures (gingivectomy, frenectomy, operculectomy, papilla flattening, uncovering temporary anchorage devices, ablation of aphthous ulcerations, and exposure of impacted teeth), fiberotomy, scanning systems, and welding procedures. In reviewing the literature on the use of laser in orthodontics, many studies have been conducted. The purpose of the present study was to give information about the use of laser in the field of orthodontics, the effects of laser during the postoperative period, and its advantages and disadvantages and to provide general information about the requirements to be considered during the use of laser.

**Keywords:** Dentistry, laser, orthodontics



## INTRODUCTION

Laser (light amplification by stimulated emission of radiation) is a term involving the concepts of light that is amplified by stimulated emission. Laser system basically consists of three components, such as the laser medium (gain medium), the pump source, and the optical cavity or optical resonator. The laser medium is the active element, and the medium determines the wavelength of the laser. The pump source stimulates the laser medium until the light energy is emitted. The optical cavity is a compartment of mirrors that contain the laser medium. The laser optical resonator amplifies the light energy that is released from the gain medium as reflected by the mirrors (fully glazed on one side and partly glazed on the opposite side of the media) back onto itself, where it may be amplified by stimulated emission before exciting the cavity (1). The generated beam of light is the laser beam.

### Laser Beam Characteristics

Laser light differs from normal light with some features. These are the following:

- Laser light is monochromatic, meaning of one color and one wavelength.
- Laser light waves all travel in the same direction, without diffusion (collimated). It is possible to reach distant areas that are difficult to reach with other tools according to the feature of laser beam that travels as a single line without diffusion.
- Same phased photons that generate the light (coherent); laser light has the potential of constructive, as well as descriptive, interference as in radio waves and sound waves. Light wave consists of the spread out of photons

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with different amplitudes, wavelengths, and frequencies (incoherent feature) according to the theory of electromagnetic wave. Laser is a light wave with the same amplitude, frequency (single frequency–single color), and temporal distribution. These point out the coherent features of laser (2).

The history of laser dates back to 1996. Laser has become the agenda with Albert Einstein's theory of propagation of light and the concept of stimulated emission in 1946, is developed with the first indication of induced radiation by W.E. Rutherford in 1947, and the discovery of the MASER system that the only difference from laser is invisible by Charles H. Townes in 1951 and Theodore Maiman realized the first working laser based on ruby crystal (Hughes Research Laboratory) (1). The use of lasers in the medical field occurs in the 1970s. After the beginning of oral surgeons using carbon dioxide ($CO_2$) laser on soft tissue in the 1980s and specifically the production of the first laser to be used in dentistry, many innovations and developments have been followed up until now. The Food and Drug Administration approved the use of erbium laser on hard tissue in 1997 and the use of the first diode laser on soft tissue after 1 year (3).



## Classification of Lasers

As there are many types of lasers used in dentistry and the medical field, it is usual to classify laser devices according to their active material. Lasers are classified into four types based on the type of laser medium used as follows:

- semiconductor lasers (diode laser)
- gas lasers
- solid-state lasers
- fiber lasers (4).

The clinical use of low-level laser therapy (LLLT) in different active environments is realized by different wavelengths measured as nanometers (nm). The frequently used types of low-level lasers and wavelengths are as follows:

- He–Ne: 633 nm
- InGaAlP: 633–700 nm
- GaAlAs (gallium–aluminum–arsenide): 780–890 nm
- GaAs: 940 nm.

In LLLT applications, there are too many factors that determine the impact of the laser beam onto the tissue. One of them is the range of the level and the duration of the effect of the used laser. Lasers with different wavelengths and levels of range have various effects on the tissues (Table 1).

## Laser–Tissue Interaction

The three main effects of lasers on the tissues are as follows:

1. photothermal effects: ablation of tissues with vaporization
2. photochemical effect: the biostimulation effect created by increasing the production of ATP
3. photoacoustic effect: dehydration, burning, and carbonization effects (5).

The factors that determine the effect of the laser beam on the tissues are the following:

a) the biological properties of the tissue (absorption power, blood circulation, minerals and water content, and tissue density)
b) the characteristics of the laser (wavelength, energy density, exposure time, continuous or pulsed, maximum pulse energy, with or without contact (contact or non-contact), and the average of pulse repetition (6).

Laser beam leads to chemical changes or thermal effects on the tissues. We can classify these thermal effects as warming (37°–60°), coagulation (60°–90°), protein denaturation (90°–100°), vaporization (100°), tissue carbonization (125°–150°), and fast cutting (>125°). These effects on the tissue depend on the low or high level of the laser (7).

# USE OF LASER IN ORTHODONTICS

The orthodontic treatment process is a long and challenging process for both the patient and the physician. Too many complications may occur in the dentoalveolar complex proportionally with the prolonged treatment duration. Laser systems are used in many fields of orthodontics practice to prevent or reduce these types of complications.

## Effects of Laser Systems on Orthodontic Tooth Movement

Many studies have been conducted to accelerate the orthodontic tooth movement. Guram et al. (8) applied low-level GaAlAs diode laser (810 nm, 5 J/cm$^2$) on 20 simple Class I bimaxillary protrusion patients to investigate orthodontic tooth movement duration and pain perception. According to the result of the study, there was a statistically significant decrease in the rate of canine retraction in the laser group compared with the control group, and pain experience was also statistically significant for the first 2 days of orthodontic treatment. As a result, it was underlined that the laser therapy is a useful procedure on orthodontic tooth movement and LLLT can reduce the fixed orthodontic treatment timing. In an in vitro study that aimed to compare the effects of

**Table 1.** The effect of lasers of different wavelengths and dose ranges on the tissues.

| Area of use | Type of laser | Wavelength $\lambda$ (nm) | Dose range (J/cm$^2$) | Effect |
|---|---|---|---|---|
| Acceleration of tooth movement (18) | GaAlAs | 810 | 7–9 | Increased macrophage response and proliferation |
| Bone regeneration (32) | Diode | 780 | 10 | Increased phagocytic activity of neutrophils |
| Condylar growth (39) | KlO3 | 630 | 56 | Increased bone formation |
| Roughening the surface of the enamel (49) | Er:YAG | 2940 | 8 | Reduction in tooth enamel |
| Mini-implant stability (56) | GaAlAs | 808 | 90 | Increased osseointegration |

LLLT, low-intensity pulsed ultrasound (LIPUS), and their combination on bone remodeling during orthodontic tooth movement in rats, there were four groups: the first group was irradiated with 940 nm diode laser, the second group with LIPUS, and the third group with a combination of both LLLT and LIPUS. The fourth group was used as the control group. It was revealed that the amount of tooth movement and the histological bone remodeling were significantly greater in the treatment groups than in the control group. Among the treatment groups, the combination group was the highest, and the LIPUS group was the lowest. As a result, the use of LLLT and LIPUS can upregulate tissue gene expressions, increase orthodontic tooth movement, and improve bone remodeling (9). Hasan et al. (10) found a statistically significant difference between the two groups (LLLT used and control groups) in the overall treatment time and the leveling and alignment improvement percentage at T1 (after 1 month of treatment commencement) and T2 (after 2 months). Fujita et al. (11) reported that low-dose laser application accelerates the tooth movement and osteoclast genesis on the pressure side of the bone by stimulating the stimulating factor of RANK/RANKL and c-fmc/macrophage colony. The stimulation mentioned here is the biostimulation caused by the application of low-level laser. However, there are opinions advocating that LLLT is not an effective method of increasing the speed of tooth movement. In the review conducted by Long et al. (12), LLLT, corticotomy, electric current, pulsed electromagnetic fields, and dentoalveolar or electromagnetic dental or periodontal distraction were compared in six fields (movement rate, movement time of the tooth to the desired distance, anchorage loss, periodontal health, pulp vitality, and root resorption) according to the effect on the speed of tooth movement. While corticotomy was found to be an effective and safe method for accelerating the amount of tooth movement compared with the other methods, it was stated that LLLT is not an effective method for increasing the speed of tooth movement.

### Biostimulation and LLLT

Biostimulation is the use of low-energy laser beam on the tissues to achieve the biological effect. Basically, it is used in wound healing and in reducing pain. The laser application giving low-dose energy up enough to increase the temperature of applied tissue not more than the normal body temperature (36.5 °C) is described as "low-dose laser therapy" (13). The most well-known theory explaining the action mechanism of therapeutic lasers is photochemical theory. According to this theory, the light is absorbed by specific molecules and is followed by some of the biological chain of events. These photoreceptors are endogenous porphyrins and molecules on the respiratory chain and increase the ATP production (14).

### Biological Effects of LLLT

The biological effects of LLLT are the following:

1. induces the release and synthesis of beta-endorphin
2. increases the production of cortisol (cortisol is the front molecule of cortisone and allows the body to fight stress caused by trauma or disease)
3. increases ATP production
4. increases both DNA functions and protein synthesis ultimately
5. neurotransmission is easy with the increase in the levels of serotonin and acetylcholine
6. mitochondrial activity is stimulated by cell replication
7. the modulation of macrophages, fibroblasts, and other cells occurs
8. cell membrane potential is regulated by Na, Cl, and K ions
9. cytokines and other chemicals that accelerate the cellular communication are released
10. arterial microcirculation increases
11. edema decreases with the increase in venous and lymphatic flow
12. inflammation decreases with the increase of leukocytes involved in phagocytosis
13. faster cell division, epithelial growth, and collagen formation are provided
14. minimal scar and decreased keloid formation occur (5).

### Reduction of Postoperative Pain

It is a known fact that postoperative pain occurs within 2–4 days following the application of orthodontic force. The relationship between the degree of force applied and pain still remains unanswered. It has been reported by many researchers that LLLT application provides an analgesic effect in various therapeutic and clinical practices (15). A study where 40 patients who were scheduled to receive orthodontic treatment were randomly divided into the laser group (810-nm gallium–aluminum–arsenic diode laser in continuous mode with the power set at 400 mW and 2 J·cm$^{-2}$) and control group was analyzed and found that the application of LLLT appears to reduce the pain and sensitivity of the tooth and gingiva associated with orthodontic treatment. Interestingly, the effect also extended to the contralateral side in the trigeminal region, indicating that LLLT treatment may have some degree of bilateral effects within the orofacial region (16). According to the results of a randomized clinical trial, a single dose of LLLT (940-nm aluminum–gallium–arsenide [Al–Ga–As] diode laser set on continuous mode with the power set at 100 mW) considerably decreased postoperative pain accompanying the placement of super-elastic NiTi wires for initial alignment and leveling (17). The laser type that is often used to reduce the pain level in orthodontic treatment is GaAlAs lasers. The mechanism under the analgesic effect of laser application is not exactly known, but some researchers thought that laser application has neuropharmacological effects on the synthesis, release, and metabolization of some mediators, such as serotonin and acetylcholine in the central level and histamine and prostaglandin in the peripheral level (18).

### Effect on Bone Regeneration

Orthodontic treatment includes many regeneration techniques with too many bones and support tissues, such as rapid maxillary expansion, distraction osteogenesis, and condylar adaptation. In vivo studies showed that the LLLT positively affects wound healing by accelerating bone regeneration, stimulating trabecular osteoid tissue formation, increasing vascularization, modulating cell functions, and supporting the acceleration of bone callus reaction (19). In a study examining the effects of diode laser use on rapid maxillary expansion, 27 individuals between the ages of 8 and 12 years were separated into two groups with and without laser application. In the laser-applied group, diode laser was applied to 10 points around the mid-palatal suture, and the changes have been followed with occlusal radiographs used for density evaluation. In conclusion, it has been found that there is an effective opening in the mid-palatal suture with LLLT and bone regeneration and healing were accelerated (19). Moawad et al. (20) described the laser-assisted rapid maxillary expansion as LARME and stated in their in vivo study on 24 subjects aged 15.5–19 years that there are more significant changes in most maxillofacial components in the laser group after the expansion phase. However, there were no significant differences with respect to retention or total treatment duration between the control and laser treatment groups. Laser applications may also be used in surgically assisted rapid palatal expansion. GaAIAs laser application accelerated bone regeneration in 13 individuals with the ages ranging from 18 to 33 and after the application of subtotal Le Fort I surgery-aided rapid maxillary expansion compared with the control group (21). The positive effects of laser applications on bone formation can be explained by rapid regeneration of blood vessels. In the study by Santiago et al. (22) on experimental dogs, soft laser (Photon Laser III) was used during sutural expansion, and they reported that laser use has stimulated the healing process during and after the expansion and contributed to suture reorganization and palatal bone osteogenesis. It is stated that with the histological sections obtained from sutural areas, the blood vessels in the laser-applied group had been distributed more uniformly and were of regular sizes similar to never opened suture, and this has affected the microcirculation and neoangiogenesis in a positive way. LLLT can also be used to accelerate the healing process after bone fractures, during mandibular distraction osteogenesis and osteoradionecrosis of the jaw, and for stimulating condylar growth (23-25).



According to the results of the study by Abtahi et al. (26) that examined the effects of LLLT on condylar growth during the mandibular advancement of rabbits, LLLT increased condylar growth during mandibular advancement with no change in articular cartilage and the thickness of fibrous tissue. According to the results of this study, functional treatment times can be shortened by LLLT.

**Orthodontic Debonding**

Laser energy provides less force application during the removal process of brackets by softening the adhesive resin material used to bond the brackets. Debonding operations with laser application are especially used effectively in ceramic brackets that have high adhesion with enamel way and in particular during the removal of ceramic brackets with the use of erbium-doped yttrium aluminum garnet (Er:YAG) laser scanning method that required lower shear bond strength than conventional methods and showed adhesive remnant index (ARI) scores between 2 and 3 (27). Laser energy may remove adhesive resin from the tooth surface through thermal softening, thermal ablation, and the effects of photoablation. The removal of ceramic brackets through Er:YAG laser is achieved with the effect of thermal softening (27). There is a possibility of diffusion of the heat generated during laser-assisted debonding to the tooth structure even leading to pulpal damage. Although it is known that a temperature increase of 5.5 °C in pulpal cavity leads to pulpal necrosis, studies showed that the diode laser with either 1 W or 3 W power for 3 s is effective in debonding the ceramic brackets without any detrimental effect on the pulp or mechanical properties of the enamel, whereas laser applications that reduce the bond strength of brackets did not cause a significant increase in pulpal cavity temperature (28). Er:YAG laser application with water cooling appeared to be a safer option by reducing resin shear bond strength and reducing the likelihood of intrapulpal temperature increase while debonding ceramic brackets (29). According to Dostalova et al. (30), the brackets were removed easily after the Er:YAG laser irradiation and temperature increase was limited for both ceramic and metal brackets; in addition, scanning electron microscopy (SEM) investigation has confirmed less damage of the enamel than non-irradiated samples. Mundethu et al. (31) used Er:YAG laser irradiation for debonding ceramic brackets with a single laser pulse and stated that the debonding process is in the majority of cases due to thermomechanical ablation in the superficial part of the adhesive layer and no additional force is necessary to remove the bracket from the tooth. SEM and light microscopy showed no damages to the enamel surface.

**Etching Procedures**

Following Buonocuore (32) using 85% of phosphoric acid to prepare the enamel's surface before direct bonding in 1955, etching with acid method in preparing the enamel surface is the most frequently used method nowadays. According to some researchers, etching of the enamel surface with chemical methods have disadvantages, such as demolition of inorganic material of enamel structure and creating a more vulnerable surface against carries attacks (33). Following the report that laser systems may remove smear layer, many laser systems have been used for etching of the enamel surface. Especially in orthodontic practice, the laser etching of the enamel has become attractive in recent years because of the user-friendly procedure and the occurrence of acid-resistant enamel surfaces after laser etching. The process of bracket bonding to the ceramic surface process is a matter of great importance in orthodontic patients with prosthetic restorations or aged composite or amalgam restorations in the mouth. In recent years, laser use on the etching of amalgam surface as in the preparation of all kinds of enamel surface has gained popularity. In a previous study, amalgam surface etching with Er,Cr:YSGG laser was compared to sandblasting technique, and the shear bonding strength of stainless steel brackets coated with laser-applied amalgam surface has been remarkably greater than those of the sandblasted group (34). In an in vi-tro study that was aimed to evaluate the shear bond strength of metal brackets to microhybrid composite restorations after four different surface preparation techniques (1-etching, 2-sand-blasting, 3- grinding, and 4-CO2 laser irradiation), it was concluded that surface preparation by sandblasting and CO2 laser pro-vides clinically acceptable results with regard to bond strength and ARI score; however, grinding and acid etching failed to produce the same results (35).

Low-energy (80 mJ) Er:YAG laser levels are supposed to decrease demineralization, as shown by calcium and phosphorous measurements from the tooth surface (36). Lasmar et al. showed that Er:YAG laser causes less reduction in calcium oxide and phosphorus pentoxide ($P_2O_5$) levels than acid etching. This reached significant levels in the $P_2O_5$ concentration, suggesting that the use of Er:YAG laser caused less demineralization than acid etching and white spot lesion formation (37). However, according to the findings by Cokakoglu et al. (38), the idea that laser etching might create remineralization microspaces by trapping free ions was rejected, and they indicated that different Er:YAG laser parameters of 1 W (100 mJ and 10 Hz) or 2 W (200 mJ and 10 Hz) for enamel conditioning cannot prevent enamel demineralization when using different adhesives.

According to Sallam et al. (39), it has been shown that there was no significant difference between the mean of shear bond strength and the etched groups, and it was concluded that the laser-etched group (1.5 W/15 Hz/Er:YAG laser) resulted in clinically accepted bond strength and could be an alternative to conventional acid etching. However, in another study (40), although high shear bonding strength has been obtained with Er:YAG laser-irradiated tooth samples prior to bonding, it was reported that enamel surfaces have been highly damaged during removal and so the acid etching method and single-step etching (self-etch) can be both used more safely in orthodontic bracket bonding.

**Laser-Assisted Polymerization**

Owing to the developments in orthodontic bonding materials, reducing the time spent during the attachment of orthodontic bonding is important for clinical success. The most common type of laser used for polymerization is argon laser. The active medium of argon laser is argon gas and in gated-pulse mode emits a visible blue and blue-green light via fiber optic tip with 488 nm and 514 nm in continuous wavelength (41). Recently, argon laser use is shown to be faster and more reliable than the conventional light-hardening method and light-emitting diode (LED) as an effective method in composite resin polymerization. It has been found that argon laser use in fluoride-released pit-fissure sealants polymerization provides a high degree of protection against cariogenic changes compared with visible light and LED polymerization (41). In a systematic review that the study protocol was based on the PRISMA statement, 20 studies were included, and according to the results, $CO_2$, Er:YAG, and Nd:YAG are the most common lasers in using ceramic brackets in orthodontics. The use of laser is an effective method in different aspects of bonding procedures for ceramic brackets, such as bonding, debonding, rebonding, and the elimination of the remaining composite on the tooth surface (42).

**Mini-implant stability**

Mini-implants have been successfully used for orthodontic anchorage in many studies. However, mini-implant failure rate has been found to be between 11% and 30% (43). The rate of mini-implant failure affects the orthodontist's decision if he might use mini-implant or not in orthodontic daily practice. Despite all the advantages, mini-implants may loosen, and mobility can increase and at the end may fail during the treatment process. It has been reported that low-dose laser and LED photobiomodulation applications have positive effects on mini-screw stability. Pinto et al. (44) examined the effect of LLLT on the mini-implants and found that fast loading of 200 g has been applied on 32 mini-implants that are placed on rabbit tibias. LLLT has been applied for 21 days, and at the end, it was found that this application has significantly enhanced the implant stability. Although in an another split-mouth randomized clinical trial that involved 15 subjects with a mean age of 20.9 (±3.4) years who required extraction of the maxillary first premolar teeth and mini-implant-supported canine retraction, a diode laser with a wavelength of 940 nm at 0, 7, 14, and 21 days after mini-implant placement was used in experimental sides. Mini-implant stability was measured using resonance frequency analysis at 0, 1, 2, 3, 4, 6, 8, and 10 weeks after implant placement; however, according to the results, there were significant difference between the groups for 3–10 weeks and no difference for the first weeks over a 10-week period, and there were no differences in mini-implant stability. At the end, LLLT cannot be recommended as a clinically useful adjunct to promoting mini-implant stability during canine retraction (45).



**Soft Tissue Procedures**

In many stages of orthodontic treatment, soft tissue incisions or augmentations may be needed. Laser-assisted incisions have so many advantages during the surgical procedures, such as topical anesthesia is sufficient most of the time before laser intervention, the closure of blood vessels and lymphatic, more clean and clear field of view, no sutural requirement, less bleeding and edema in the postoperative period, and increased patient satisfaction (46). The areas of use of laser methods in soft tissue surgery in orthodontics include bonding preparation of teeth that the eruption has not been completed, removal of soft tissue on impacted canines and to do bonding in the same session, removal of excess tissue formed following the closure of large diastemas, bonding of second molar teeth by the removal of surround operculum, removal of hypertrophic and inflamed gingival tissues formed as a result of poor oral care, treatment of aphthous ulcers, correction of hyperpigmentation and crown lengthening by gingiva and shaping, and removal of high frenulum attachments (47). To et al. (48) compared the efficiency of laser-assisted gingivectomy (test group) and non-surgical periodontal therapy (control group) during fixed orthodontic treatment on patients with gingival hyperplasia. This comparison was made with the evaluation of five periodontal parameters (plaque index, gingival index, bleeding in probing, pocket depth, and gingival growth index), and as a result, a significant improvement was observed in both the test group and control group, and in the early stages of treatment for gingival index, pocket depth, and gingival growth parameters, more significant level of improvement was found in the test group.

**Laser-Assisted Circumferential Supracrestal Fiberotomy**

Long-term treatment stability in orthodontic treatment has always been an issue that needed to be focused on. One of the major reasons for the occurrence of relapse after orthodontic tooth movement is an the elastic supracrestal gingival fibril network (49). While collagenous fibers complete their reorganizations within 4–6 months, elastic supracrestal fibrils remodel slowly and are capable of generation of enough force to move the teeth even after 1 year after the completion of orthodontic treatment (42). In a randomized controlled clinical trial that compared the tendency of mandibular incisor's rotational relapse after conventional circumferential supracrestal fiberotomy (CSF) with Er,Cr:YSGG laser-aided CSF, it was concluded that laser-aided CSF in 1 month was as effective in reducing rotational relapse tendency of mandibular incisor teeth as conventional CSF and also probing depth, clinical crown height, and experienced pain levels exhibited negligible differences between the groups (50). According to the result of the study by Kim et al. (51), evaluating the effects of laser-assisted CSF and LLLT on the relapse of rotating teeth on test the dogs, laser-assisted CSF reduced the relapse when used on rotated teeth and support and did not cause any damage on periodontal structures, but LLLT application on rotated teeth increased the tendency of relapse without retainer. In a systematic review that aimed to evaluate the efficacy of LLLT on relapse of corrected tooth rotations, it was concluded that the effect of LLLT on relapse of corrected tooth rotations is related to energy density, and that low-energy density appears to incerase relapse, whereas high-energy density may reduce the relapse (52).



**Laser Scanning Systems**

Laser scanning systems can be used as soft tissue scanner, and three-dimensional (3D) images can be created using various techniques. The images created using this technique can be used for the publication of normative population data, to evaluate the results of treatment in advance for cross-sectional changes in growth, and to assess the treatment of the head and neck areas with or without surgery. 3D orthodontic scanning pattern done with laser scanning is a reliable method in arch–width and arch–length measurements on dental casts (53).

Many measurements and evaluations can be done on the models with laser scanning, including surface, area, and millimetric measurements. Noninvasive systems such as stereophotogrammetry can produce a 3D surface model from multiple viewpoints in a synchronized manner with a short capture time and clinically acceptable accuracy (54). Although the successful use of stereophotogrammetry has been reported for facial scanning, laser facial scanning is an alternative technique to stereophotogrammetry and has been successfully introduced into the workflow for making facial measurements and roducing facial protheses (55,56). As with stereophotogrammetry, laser scanning of deeper regions and undercuts of face is limited by the separation of the laser-line generator and the receptor camera (55). In addition, some facial laser scanning systems will require the patient to remain motionless for a prolonged time which could further limit data acquisition (57).

**Welding Processes in Orthodontics**

Laser welding is one of the very recent yet versatile techniques used in dentistry, which is capable of manufacturing good quality weld joints with remarkable consistency. In addition, there are many ways for welding, such as soldering, resistance (spot) welding, plasma (torch) welding, and single pulse tungsten inert gas welding (4). The primary use of industrial lasers is to ensure the fusion of two metals without welding agents. It has been stated that other than laser use in the intraoral field, laser use in laboratory procedures are stronger than bonding with solder-ing material. Laser welding devices allow for welding on ortho-dontic devices in many different ways without soldering agents (58). Thus, heterogenetic orthodontic wires made of metal alloys of different components can be generated (59). Laser welding devices have advantages by making possible to manufacture the components of devices to be used in orthodontics, ensur-ing more durable connection than conventional welding agents (58). However, the laser devices can also be used in the intraoral environment. Studies showed that the lasers are biologically harmless for the periodontal tissues adjacent the laser welded ares, alveolar bone, and pulp tissue and have no thermal effect (60).

## CONCLUSION

Laser system has far been the latest addition among these technologies that clearly have made an exceptional impact because of its minimal side effects, high precision level, and biocompatibility. There are many laser types determined for dental use, and laser systems have a wide range of applications in the fields of orthodontics and dentistry. Laser systems may be an exceptional modality of orthodontic treatment for many clinical conditions when used effectively. Although lasers have many advantages, it is important to determine the effective laser type and wavelength to meet all requirements in both soft and hard tissues, and the orthodontist should consider some points before using the laser that includes relatively high cost of the devices, needs additional education (especially in basic physics), every wavelength has different properties, and needs implementation of safety measures. In many areas of orthodontics, there are different types of lasers that can be used, but hence there is no single laser type that can meet all requirements in both hard and soft tissues; in routine practice, the orthodontist should analyze well for what purpose to use the system. In addition, in the literature, even if the effectiveness of soft tissue laser applications is generally indicated, there are conflicting results in applications, such as accelerating tooth movement, hard tissue laser applications, reducing relapse, etching operations, and mini-implant stability. Further randomized controlled studies with larger sample size are required to clarify these controversial results regarding the effectiveness of laser systems in orthodontic applications.

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## REFERENCES


1. Coluzzi DJ. Fundamentals of dental lasers: science and instruments. Dental Clinics. 2004; 48: 751-70. [CrossRef]
2. Frentzen M, Koort H. Lasers in dentistry: new possibilities with advancing laser technology? Int Dental J 1990; 40:3 23-32.
3. Coluzzi DJ. An Overview of Lasers in Dentistry. 2011.
4. Perveen A, Molardi C, Fornaini C. Applications of laser welding in dentistry: a state-of-the-art review. Micromachines (Basel) 2018; 9: pii: E209. doi: 10.3390/mi9050209. [CrossRef]
5. Genc G, Kocadereli I, Tasar F, Kilinc K, El S, Sarkarati B. Effect of low-level laser therapy (LLLT) on orthodontic tooth movement. Lasers Med Sci 2013; 28: 41-7. [CrossRef]
6. Wigdor H, Abt E, Ashrafi S, Walsh JT. The effect of lasers on dental hard tissues. J Am Dent Assoc 1993; 124: 65-70. [CrossRef]
7. Romanos GE. Clinical applications of the Nd: YAG laser in oral soft tissue surgery and periodontology. J Clin Laser Med Surg 1994; 12: 103-8. [CrossRef]
8. Guram G, Reddy RK, Dharamsi AM, Ismail PMS, Mishra S, Prakashkumar MD. Evaluation of low-level laser therapy on orthodontic tooth movement: a randomized control study. Contemp Clin Dent 2018; 9: 105-9.
9. Alazzawi MMJ, Husein A, Alam MK, Hassan R, Shaari R, Azlina A, et al. Effect of low level laser and low intensity pulsed ultrasound therapy on bone remodeling during orthodontic tooth movement in rats. Prog Orthod 2018; 19: 10. doi: 10.1186/s40510-018-0208-2. [CrossRef]
10. AlSayed Hasan MMA, Sultan K, Hamadah O. Low-level laser therapy effectiveness in accelerating orthodontic tooth movement: A randomized controlled clinical trial. Angle Orthod 2016; 87: 499-504. [CrossRef]
11. Fujita S, Yamaguchi M, Utsunomiya T, Yamamoto H, Kasai K. Low-energy laser stimulates tooth movement velocity via expression of RANK and RANKL. Orthod Craniofac Res 2008; 11: 143-55. [CrossRef]
12. Long H, Pyakurel U, Wang Y, Liao L, Zhou Y, Lai W. Interventions for accelerating orthodontic tooth movement: a systematic review. Angle Orthod 2012; 83: 164-71. [CrossRef]
13. Lim H-M, Lew KK, Tay DK. A clinical investigation of the efficacy of low level laser therapy in reducing orthodontic postadjustment pain. Am J Orthod Dentofacial Orthop 1995; 108: 614-22. [CrossRef]
14. Yamaguchi M, Hayashi M, Fujita S, Yoshida T, Utsunomiya T, Yamamoto H, et al. Low-energy laser irradiation facilitates the velocity of tooth movement and the expressions of matrix metalloproteinase-9, cathepsin K, and alpha (v) beta (3) integrin in rats. Eur J Orthod 2010; 32: 131-9. [CrossRef]
15. Marini I, Bartolucci ML, Bortolotti F, Innocenti G, Gatto MR, Bonetti GA. The effect of diode superpulsed low-level laser therapy on experimental orthodontic pain caused by elastomeric separators: a randomized controlled clinical trial. Lasers Med Sci 2015; 30: 35-41. [CrossRef]
16. Wu S, Chen Y, Zhang J, Chen W, Shao S, Shen H, et al. Effect of low-level laser therapy on tooth-related pain and somatosensory function evoked by orthodontic treatment. Int J Oral Sci 2018; 10: 22. doi: 10.1038/s41368-018-0023-0. [CrossRef]
17. Qamruddin I, Alam MK, Abdullah H, Kamran MA, Jawaid N, Mahroof V. Effects of single-dose, low-level laser therapy on pain associated with the initial stage of fixed orthodontic treatment: A randomized clinical trial. Korean J Orthod 2018; 48: 90-7. [CrossRef]
18. Eslamian L, Borzabadi-Farahani A, Hassanzadeh-Azhiri A, Badiee MR, Fekrazad R. The effect of 810-nm low-level laser therapy on pain caused by orthodontic elastomeric separators. Lasers Med Sci 2014; 29: 559-64. [CrossRef]
19. Cepera F, Torres FC, Scanavini MA, Paranhos LR, Capelozza Filho L, Cardoso MA, et al. Effect of a low-level laser on bone regeneration after rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2012;141: 444-50. [CrossRef]
20. Moawad SG, Bouserhal J, Al-Munajed MK. Assessment of the efficiency of Erbium-YAG laser as an assistant method to rapid maxillary expansion: An in vivo study. Int Orthod 2016; 14: 462-75. [CrossRef]
21. Angeletti P, Pereira MD, Gomes HC, Hino CT, Ferreira LM. Effect of low-level laser therapy (GaAlAs) on bone regeneration in midpalatal anterior suture after surgically assisted rapid maxillary expansion. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109: e38-46. [CrossRef]
22. Santiago VC, Piram A, Fuziy A. Effect of soft laser in bone repair after expansion of the midpalatal suture in dogs. Am J Orthod Dentofacial Orthop 2012; 142: 615-24. [CrossRef]
23. Ribeiro GH, Minamisako MC, Rath IBdS, Santos AMB, Simões A, Pereira KCR, et al. Osteoradionecrosis of the jaws: case series treated with adjuvant low-level laser therapy and antimicrobial photodynamic therapy. J Appl Oral Sci 2018; 26: doi: 10.1590/1678-7757-2017-0172. [CrossRef]
24. Gurler G, Gursoy B. Investigation of effects of low level laser therapy in distraction osteogenesis. J Stomatol Oral Maxillofac Surg 2018; 119: 469-76. [CrossRef]
25. Okşayan R, Sökücü O, Üçüncü N. The effects of low-level laser therapy on condylar growth with a mandibular advancement appliance in rats. Photomed Laser Surg 2015; 33: 252-7. [CrossRef]
26. Abtahi M, Poosti M, Saghravanian N, Sadeghi K, Shafaee H. The effect of low level laser on condylar growth during mandibular advancement in rabbits. Head Face Med 2012; 8: 4. doi: 10.1186/1746-160X-8-4. [CrossRef]
27. Oztoprak MO, Nalbantgil D, Erdem AS, Tozlu M, Arun T. Debonding of ceramic brackets by a new scanning laser method. Am J Orthod Dentofacial Orthop 2010; 138: 195-200. [CrossRef]
28. Sinaee N, Salahi S, Sheikhi M. Evaluation of the effect of diode laser for debonding ceramic brackets on nanomechanical properties of enamel. Dent Res J (Isfahan) 2018; 15: 354-60. [CrossRef]
29. Nalbantgil D, Tozlu M, Oztoprak MO. Pulpal thermal changes following Er-YAG laser debonding of ceramic brackets. ScientificWorldJournal 2014; 2014: doi: 10.1155/2014/912429. [CrossRef]
30. Dostálová Tj, Remeš M, Jelínková H, Šulc J, Němec M, Vyhlídal D, editors. Er: YAG laser metal and ceramic bracket debonding. Lasers in Dentistry XXII; 2016: International Society for Optics and Photonics. [CrossRef]
31. Mundethu AR, Gutknecht N, Franzen R. Rapid debonding of polycrystalline ceramic orthodontic brackets with an Er: YAG laser: an in vitro study. Lasers Med Sci 2014; 29: 1551-6. [CrossRef]
32. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res 1955; 34: 849-53. [CrossRef]
33. Corpas-Pastor L, Villalba Moreno J, de Dios Lopez-Gonzalez Garrido J, Pedraza Muriel V, Moore K, Elias A. Comparing the tensile strength of brackets adhered to laser-etched enamel vs. acid-etched enamel. J Am Dent Assoc 1997; 128: 732-7. [CrossRef]
34. Oskoee PA, Kachoei M, Rikhtegaran S, Fathalizadeh F, Navimipour EJ. Effect of surface treatment with sandblasting and Er, Cr: YSGG laser on bonding of stainless steel orthodontic brackets to silver amalgam. Med Oral Patol Oral Cir Bucal 2012; 17: e292-6. [CrossRef]
35. Zarif Najafi H, Mousavi M, Nouri N, Torkan S. Evaluation of the effect of different surface conditioning methods on shear bond strength of metal brackets bonded to aged composite restorations. Int Orthod 2019; 17: 80-8. [CrossRef]

36. Cecchini RCM, Zezell DM, de Oliveira E, de Freitas PM, Eduardo CdP. Effect of Er: YAG laser on enamel acid resistance: Morphlogical and atomic spectrometry analysis. Lasers Surg Med 2005; 37: 366-72. [CrossRef]
37. Lasmar M, Reher V, Lalloo R, Reher P. Enamel demineralization and bracket bond strength when etching with acid and/or Er: YAG laser. Aust Dent J 2012; 57: 190-5. [CrossRef]
38. Çokakoğlu S, Nalçacı R, Üşümez S, Malkoç S. Effects of different combinations of Er: YAG laser-adhesives on enamel demineralization and bracket bond strength. Photomed Laser Surg 2016; 34: 164-70. [CrossRef]
39. Sallam RA, Arnout EA. Effect of Er: YAG laser etching on shear bond strength of orthodontic bracket. Saudi Med J 2018; 39: 922-7. [CrossRef]
40. Türköz Ç, Ulusoy Ç. Evaluation of different enamel conditioning techniques for orthodontic bonding. Korean J Orthod 2012; 42: 32-8. [CrossRef]
41. Das U, Prashanth S. A comparative study to evaluate the effect of fluoride releasing sealant cured by visible light, argon laers, and light emitting diode curing units: An in vitro study. J Indian Soc Pedod Prev Dent 2009; 27: 139-44. [CrossRef]
42. Matini NS, Motabar M. Current Status for Laser-Assisted Orthodontics in the Application of Ceramic Brackets. J Lasers Med Sci 2018; 9.
43. Kravitz ND, Kusnoto B. Risks and complications of orthodontic miniscrews. Am J Orthod Dentofacial Orthop 2007; 131(4 Suppl): S43-51. [CrossRef]
44. Pinto MR, dos Santos RL, Pithon MM, de Souza Araújo MT, Braga JPV, Nojima LI. Influence of low-intensity laser therapy on the stability of orthodontic mini-implants: a study in rabbits. Oral Surg Oral Med Oral Pathol Oral Radiol 2013; 115: e26-30. [CrossRef]
45. Abohabib AM, Fayed MM, Labib AH. Effects of low-intensity laser therapy on the stability of orthodontic mini-implants: a randomised controlled clinical trial. J Orthod 2018; 45: 149-56. [CrossRef]
46. Seifi M, Matini NS. Laser surgery of soft tissue in orthodontics: Review of the clinical trials. J Lasers Med Sci 2017; 8(Suppl 1): S1-6. [CrossRef]
47. Kulkarni RB, Misal A, Mishra R. Soft tissue diode laser in orthodontics. Int J Appl Dent Sci 2017; 3: 91-4.
48. To TN, Rabie AB, Wong RW, McGrath CP. The adjunct effectiveness of diode laser gingivectomy in maintaining periodontal health during orthodontic treatment. Angle Orthod 2013; 83: 43-7. [CrossRef]
49. Edwards JG. A study of the periodontium during orthodontic rotation of teeth. Am J Orthod 1968; 54: 441-61. [CrossRef]
50. Miresmæili AF, Mollabashi V, Gholami L, Farhadian M, Rezaei-Soufi L, Javanshir B, et al. Comparison of conventional and laser-aided fiberotomy in relapse tendency of rotated tooth: A randomized controlled clinical trial. Int Orthod 2019; 17: 103-13. [CrossRef]
51. Kim SJ, Paek JH, Park KH, Kang SG, Park YG. Laser-aided circumferential supracrestal fiberotomy and low-level laser therapy effects on relapse of rotated teeth in beagles. Angle Orthod 2010; 80: 385-90. [CrossRef]
52. Meng M, Yang M, Lv C, Yang Q, Yang Z, Chen S. Effect of low-level laser therapy on relapse of rotated teeth: A systematic review of human and animal study. Photomed Laser Surg 2017; 35: 3-11. [CrossRef]
53. Erten O, Yılmaz BN. Three-Dimensional Imaging in Orthodontics. Turk J Orthod 2018; 31: 86-94. [CrossRef]
54. Sabol JV, Grant GT, Liacouras P, Rouse S. Digital image capture and rapid prototyping of the maxillofacial defect. J Prosthodont 2011; 20: 310-4. [CrossRef]
55. Cheah CM, Chua CK, Tan KH, Teo CK. Integration of laser surface digitizing with CAD/CAM techniques for developing facial prostheses. Part 1: design and fabrication of prosthesis replicas. Int J Prosthodont 2003; 16: 435-41.
56. Ciocca L, Mingucci R, Gassino G, Scotti R. CAD/CAM ear model and virtual construction of the mold. J Prosthet Dent 2007; 98: 339-43. [CrossRef]
57. Jablonski RY, Osnes CA, Khambay BS, Nattress BR, Keeling AJ Accuracy of capturing oncology facial defects with multimodal image fusion versus laser scanning. J Prosthet Dent 2019; 122: 333-8. [CrossRef]
58. Hurt AJ. Digital technology in the orthodontic laboratory. Am J Orthod Dentofacial Orthop 2012; 141: 245-7. [CrossRef]
59. Watanabe E, Stigall G, Elshahawy W, Watanabe I. Deflection load characteristics of laser-welded orthodontic wires. Angle Orthod 2011; 82: 698-702. [CrossRef]
60. Fornaini C, Bertrand C, Rocca J, Mahler P, Bonanini M, Vescovi P, et al. Intra-oral laser welding: an in vitro evaluation of thermal increase. Lasers Med Sci 2010; 25: 473-7. [CrossRef]

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Interview

# Interview with Dr.Ravindra Nanda on Current Concepts in Orthodontics

Dr.Ravindra Nanda is Professor Emeritus, Former UConn Alumni Endowed Chair and Head of the Department of Craniofacial Sciences and Division of Orthodontics, University of Connecticut, USA. Dr.Nanda, a renowned researcher and lecturer in Orthodontics, has been author of many books and scientific articles. He is on the Editorial Board of Turkish Journal of Orthodontics.

The editors of Turkish Journal of Orthodontics (TJO) did an interview with Dr.Ravindra Nanda about current concepts in orthodontics.



**TJO:** What has been the most important innovation of the past 20 years in orthodontics?

**Dr. Nanda:** I will have to say Aligners. They have changed the way we practice today.

**TJO:** What should be the case selection criteria in aligner treatments? And we would like to ask your opinion as an expert in biomechanics, if a paradigm shift occurred in terms of biomechanics while treating cases with clear aligners?

**Dr. Nanda:** My views have changed significantly over the last five years. Now I feel one can treat most of the malocclusions if done properly. I am not sold yet on aligner treatment of adolescent patients. Biomechanics principles are universal but for aligners there are quite a few differences. Major issue is deformation of aligners which makes it difficult to analyse force system the same way as we can with braces. Attachments have played a nice role in applying forces on teeth but their shape, size, site and angular positioning can affect the type of tooth movement. More studies are needed to improve our understanding of effect of non continuous forces, compliance , aligner material and attachments. Unfortunately, aligner companies are pushing treatment of even 4 and 5 years old or patients with growth discrepancies. There is no research to support these treating kids with aligners.

**TJO:** Do you think the evolution of the clear aligners will bring to an end to braces?

**Dr. Nanda:** Braces are not going anywhere. Aligners have some unresolved issues such as compliance, aligner material, and treatment of transverse and a-p discrepancies, and I can go on.

**TJO:** Do you use temporary anchorage devices frequently, and what should we take into consideration while using TAD's?

**Dr. Nanda:** I am personally retired now from active practice. I would say at our university probably 15% of patients receive TADs. In our eyes if biomechanics and differential moments are used properly, use of TADs becomes redundant. In my view TADs are ideal for en masse movements, molar intrusions, large space closures, major midline corrections and multidisciplinary patients.

**TJO:** Do you treat all your orthognathic surgery cases with 'the surgery first protocol'? And do you take advantage of the temporary anchorage devices in these cases?

**Dr. Nanda:** We feel majority of the orthognathic surgery patients can be managed by Surgery First protocol. Some patients may need minor pre surgery treatment if some teeth may prevent proper post surgical occlusion. Yes, TADs can be placed if major movement of teeth is required post surgery.