Original Article

Reliability of Expected Root Position in Two Different Bracket Bonding and Positioning Techniques (A Comparative Ex-Vitro Study)

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Abstract

Objective: To measure the reproducibility of expecting root position (ERP) in various brackets bonding and positioning techniques.

Methods: Twenty Angle's Class-I typodont models were divided into four groups of five models each. The first two groups were bonded directly, and the other two groups were bonded indirectly. Intraoral scanning and CBCT were taken before and after simulation orthodontic treatment for each model. The pre-treatment CBCT of models was matched to the digital crown of the post-treatment intraoral scanner of the models in order to put the root in the expected position. At the same time, the true root position was obtained from the CBCT of post-treated models. Finally, the true and ERPs were superimposed by part comparison analysis function in 3-Matic software to measure mm displacement between two compared parts. The intra-examiner reliability was tested by the Bland-Altman method. One-way ANOVA was used to compare the displacement means of true and ERP.

Results: There was no significant difference between the mean of true and ERP among the study groups for maxillary and mandibular arches (P>0.05).

Conclusions: Combining data from CBCT and the digital models, simulation of the root positions was statistically validated with direct and indirect techniques of bracket positioning and bonding.

Keywords: *Expected root position, CBCT, Bracket bonding, Bracket positioning.*

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Introduction

Successful orthodontic treatment plans depend on the accuracy of the three-dimensional positioning of crowns and roots for proper functioning, esthetics, and stable normal occlusion [1]. The principles are Andrew's six keys, which are (molar relationship, rotations, spaces, occlusal planes, mesiodistal angulation, and buccolingual inclination)[2]. However, the first four keys depend on the study of tooth crowns, while the last two keys depend on both crown and root position[3]. Improper root positions may increase the risk of relapse, periodontal damage, and unwanted tooth movements under occlusal loads[4-6].

Current monitoring root positions are orthopantomogram (OPG) and cone-beam computed tomography (CBCT). OPG has many limitations like magnification, distortion, superimposition, and misrepresentation of structures[7-10]. CBCT uses relatively larger amounts of radiation compared to OPG [11-14], while its potential of multi-planar reconstruction allows interpretation without the superimposition of structures[15]. It must be stated that significant efforts are being made to reduce CBCT dosages to the point where it's like the OPG and cephalometric radiographic dosages[16]. Moreover, CBCT synthesizes panoramic views with the advantages of eliminating magnification, ghost images, distortion, and overlaps, unlike conventional OPG[17].

Recent studies have introduced a new methodology to track root position with a single pre-treatment CBCT image and post-treatment intraoral scans (IOS)[1,3,18-22]. However, these studies were all done on the clinical crown's long axis (LACC) bracket positioning and direct bonding techniques. The goal of this study was to compare the method of expecting root positions (ERP) in various bracket bonding and positioning to measure its reproducibility with different techniques. The null hypothesis was that there would be no differences in ERP by using different techniques (direct and indirect) of bracket positioning and bonding.

Materials and methods

The sample consisted of 20 simulated Angle class I typodont models with moderate crowding (4-6 mm space deficiency) in both arches. The teeth were not displaced severely to allow ideal bracket placement. The typodont was custom-made from the Zhengzhou Smile Industrial Co., China. Each typodont contained twenty-eight artificial acrylic teeth in pre-formed typodont wax. The research was conducted at the College of Dentistry/ Sulaimani University in collaboration with the private Suli-Orthodontics clinic.

Typodont models were divided into four groups according to their method of bracket bonding (direct/indirect) and bracket positioning (the long axis of the clinical crown (LACC) or the long axis of the tooth (LAT) oriented). Every five typodont models were assigned to one group (Figure 1). IOS was used for the indirect bonding techniques, and CBCTs were taken for each typodont model as initial records. The typodonts were scanned with 3Shape TRIOS wireless pod IOS (3Shape company, Denmark 2015). CBCTs were taken with Galileos type CBCT machine (Sirona, 2016, Germany) used with SidexisXG software, set at 98 kVp, 30 mA.

Techniques for the bracket bonding and positioning in different groups:

Direct crown oriented (DCO) group

Brackets were bonded directly, and their positions were determined by looking at the crowns directly. Vertical bracket and tube positions were determined, according to Bennett and McLaughlins' non-extraction bracket placement charts for average-sized teeth in adults (Table1)[23].

Andrews' LACC was used as the key reference line for the mesiodistal and axial positioning of the brackets. LACC extended to the root surface for root long axis determination (LAT). Horizontal bracket positioning is achieved when the mesiodistal center of the tooth coincides with the brackets' center. Axial positioning was achieved when the incisal edges were parallel with the bracket slots[24].

Direct crown and root oriented (DCR) group

The brackets were bonded directly, and their positions were determined by looking at the crown and roots directly. This procedure was done by removing labial/buccal wax from the artificial teeth' roots; then, all the teeth were brought out separately. Their LACC was extended to the root surfaces for the determination of LAT. This is impossible on the natural teeth but was done as the gold standard only for comparison with ICR.

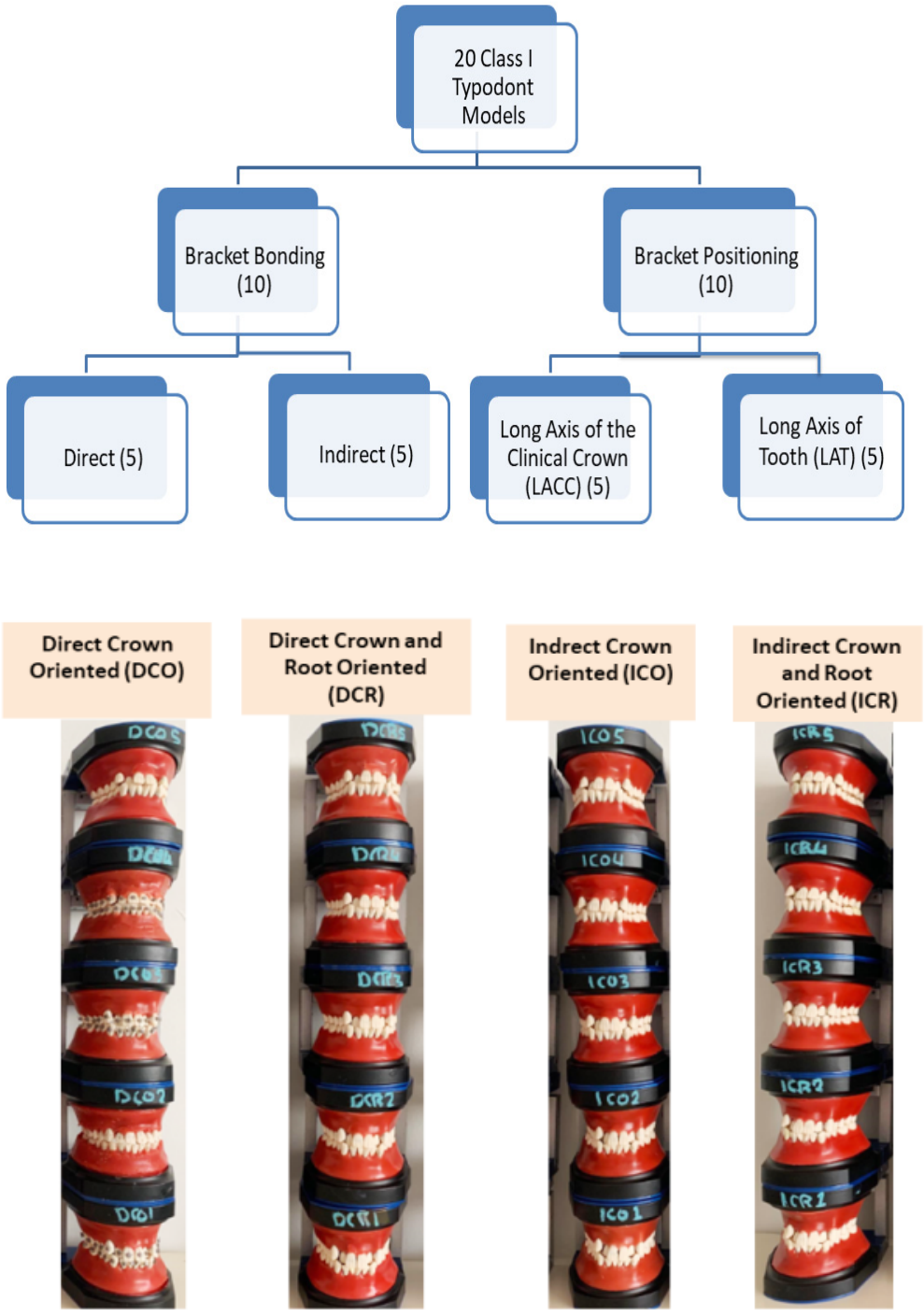

Figure 1: Distribution of the sample.

Table 1: Upper and lower bracket placement charts, with recommended values for non-extraction cases[23].

Arch	1	2	3	4	5	6	7
Upper	5.0	4.5	5.0	4.5	4.0	3.0	2.0
Lower	4.0	4.0	4.5	4.0	3.5	2.5	2.5

The bracket positions were determined, as illustrated in the DCO group.

Indirect crown oriented (ICO) group

Initially, the IOS of the model was prepared for bracket positioning with Ortho analyzer software (3Shape, Copenhagen/ Denmark). The brackets were bonded indirectly, and bracket positions were determined by looking at LACC on the IOS crown by Ortho Analyzer software. The model with brackets from Ortho Analyzer was exported to Appliance Designer software (3Shape, Copenhagen/ Denmark, 2015). In the software, the brackets were blocked-out virtually to remove the tray during bracket bonding. A line was drawn for demarcating the transfer tray of indirect bonding. The transfer tray was printed, the brackets were placed in their hole in the tray and bonded to the artificial teeth on the typodont.

Indirect crown and root oriented (ICR) group

The model preparation and indirect bonding transfer trays were made in the same way as in the ICO group. The bracket positions were determined by looking at LAT on merged CBCT root with IOS crown (composite tooth) by Ortho Analyzer software. The composite teeth were formed by importing pre-treatment Digital Imaging and Communications in Medicine (DICOM) files obtained by pre-treatment CBCT to Ortho Analyzer software. Then, the IOS crown of the corresponding models was superimposed on it by pressing the align CT scan button, which is found in the model alignment section in the software.

Orthodontic treatment was simulated on all groups of typodont models. A complete set of metal brackets – Roth (Dentaurum miniequilibrium) with a pre-adjusted 0.022 * 0.028-inch (in) slot was used. None of the brackets had hooks (except for canine brackets and molar tubes) to avoid any potential interference when they were bonded. Ortho-Cast M-Series mini buccal tubes from Dentaurum were used for the first and second molars. A total of 400 brackets and 160 tubes were used. Nickle-titanium archwire of 0.014-in was tied to the brackets on all models. The typodonts were then submerged into a two-holed, temperature control, hot, water bath at 125° F (51.6°C) for half an hour. The dental wax of the typodonts softened in hot water, allowing accelerated tooth movement. After that, the typodonts were brought out and allowed to cool at room temperature to stop further tooth movement. Then, typodont wax was added to the cleared areas because of tooth movement to allow the archwire to change with the teeth fixed in their place. This procedure was repeated consecutively using archwire (0.016, 0.016 * 0.022 in nickel-titanium, and 0.016 * 0.022, 0.017*0.025-in stainless steel) until the treatment was completed. The last wire (power chain, closed type) was used to close all spaces between the teeth. Finally, IOS and CBCT were taken for all the models after removing the brackets.

Expected root position formation

Digital Imaging and Communications in Medicine data obtained from the CBCT scan of the pre-treatment typodont was imported to Mimics software (version 22.0; Materialise, Leuven, Belgium) for threshold segmentation and mask creation. The threshold segmentation of 2285 to 3071grayscale level applied to minimize the surrounding wax resulted in creating a three-dimensional (3D) virtual surface of the teeth. Then, this file was exported to 3-Matic software (version 14.0; Materialise, Leuven, Belgium) with the stereolithography (STL) obtained from intraoral scanning of the post-treatment models. The pre-treatment CBCT crown parts of the teeth were then superimposed onto their respective post-treatment 3shape crown parts in 3-Matic. This procedure puts the root of the teeth in ERP. The Maxillary and mandibular arches were superimposed separately.

Part comparison analysis function was used to calculate accurate superimposition, and the color bar chart was automatically generated to show the amount of mm displacement between different parts (Figure 2). The minimum values of mm displacement between parts are shown in the dark blue, transition to zero displacements are shown in aqua, the zero displacements appear light green, the transition from zero is yellow, and the maximum values are shown as red.

Superimposition of expected and true root position

The DICOM data gained from post-treatment CBCT was also imported to the Mimics software. Threshold segmentation was applied to the post-treatment CBCT

scan to generate 3D virtual surface models of the maxillary and mandibular dental arches, which are true root position models. Then, these virtual surface models of the dental arches were exported into 3-Matic software. In the software, they were superimposed on the already created ERP. Before superimposition, the IOS of ERP was removed to allow accurate superimposition (Figure 3). Part comparison analysis function was used to calculate accurate superimposition, and the color bar chart was automatically generated to show the amount of mm displacement between different parts.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS, version 22) was used for the data analysis. A one-way ANOVA test was used to compare mm differences between the true and expected roots position displacements of the study groups. A p-value of ≤ 0.05 was considered statistically significant. Color bar charts for the comparison between expected and true root positions were automatically generated in the 3-Matic software. The Bland-Altman method was applied to assess the intra-operator reliability.

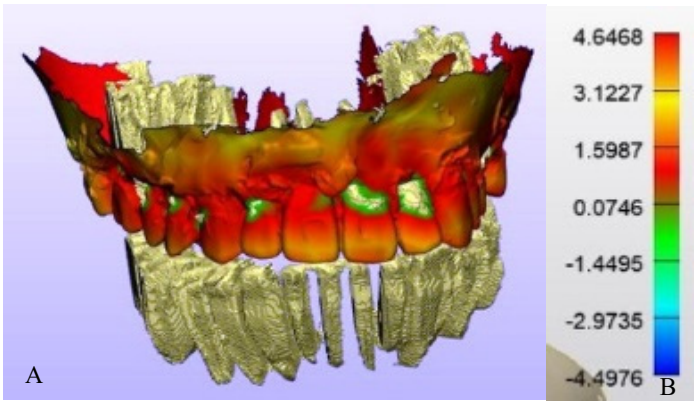

Figure 2: a) Expected root position formation by joining post-treatment intraoral scanned crowns and pre-treatment CBCT roots, b) Color bar chart that shows minimum displacement between the CBCT crown and intraoral scanned crown.

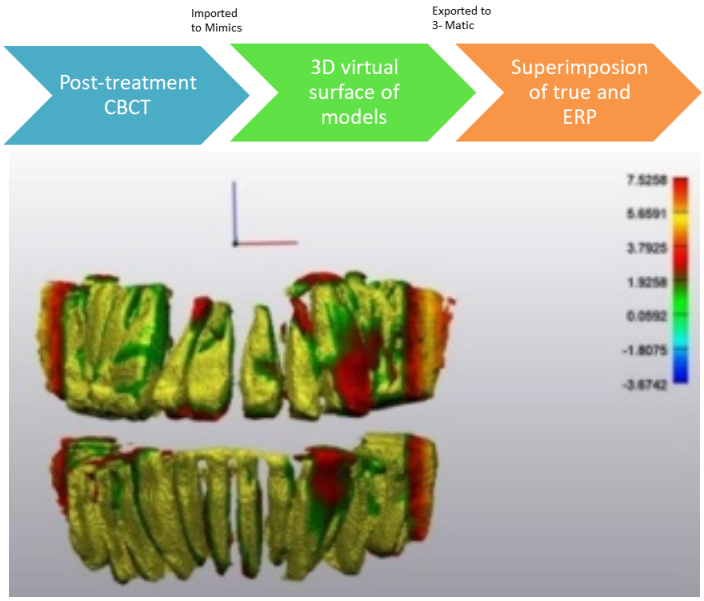

Figure 3: Superimposition of expected and true root positions.

Results

The descriptive statistics for the displacement mean between expected and true root positions of each group were calculated and summarized in Table 2.

Moreover, a One-way ANOVA test was used to compare the true and expected root position displacements.

As shown in Table 3, the p-value was 0.997 for maxilla and 0.999 for mandible that addressed non-significance difference.

To assess the reliability and reproducibility of the ERP, all variables of ERP were measured twice with a one-week interval and were then tested by the Bland-Altman method, which showed agreement for all the measurements (Figure 4).

Discussion

Proper function, esthetics, and stable occlusion depend on proper root positioning[1]. The American Board of Orthodontics has counted proper root positions in their scoring system. Points would be deducted if the adjacent roots were not parallel with each other. Although they recommend OPG in the assessment of root angulation, according to the American Board of Orthodontics, OPG is frequently associated with distortions that affect the root angulation decisions[18-22]. The CBCT scan is the right substitution for the OPG that accurately captures the tooth root position three-dimensionally. However, its radiation dose is high. Thus, a new ERP approach can be used to monitor the root position precisely on a more frequent basis with minimal radiation. This approach has been statistically validated[18-22]. While no studies are using such methodology on a large sample or comparing ERP in different bracket bonding and positioning techniques, therefore in the current study, these two subjects have studied to fill the gap in the literature in this area.

The sample size determination of the present study was done by reference to the pilot study of Lee et al.[21], that found 15 samples was enough to conduct an ERP study with adequate statistical power. While in this study, the sample size was increased to 20, which gave more statistical power to the study, it also can reduce type II error.

Table 2: Descriptive statistics for the mean of displacement between expected and true root positions.

	Mean (mm)	Lower bound	Upper bound	Median (mm)	±SD	Range Minimum	Maximum
DCO							
Maxilla	0.176	0.093	0.259	0.150	±0.067	0.110	0.270
Mandible	0.182	0.120	0.244	0.190	±0.050	0.110	0.240
DCR							
Maxilla	0.184	0.111	0.257	0.180	±0.059	0.110	0.260
Mandible	0.180	0.110	0.250	0.170	±0.057	0.120	0.270
ICO							
Maxilla	0.182	0.115	0.249	0.190	±0.054	0.110	0.250
Mandible	0.178	0.093	0.263	0.150	±0.069	0.110	0.270
ICR							
Maxilla	0.182	0.099	0.265	0.180	±0.066	0.100	0.270
Mandible	0.178	0.146	0.210	0.180	±0.026	0.140	0.210

Table 3: Expected and true root position displacement means for the maxilla and mandible.

	Mean (mm)	±SD	SE	p-value*
Maxilla				
DCO	0.176	±0.067	0.030	0.997
DCR	0.184	±0.059	0.026	
ICO	0.182	±0.054	0.024	
ICR	0.182	±0.066	0.030	
Total	0.181	±0.057	0.013	
Mandible				
DCO	0.182	±0.050	0.022	0.999
DCR	0.180	±0.057	0.025	
ICO	0.178	±0.069	0.031	
ICR	0.178	±0.026	0.012	
Total	0.180	±0.048	0.011	

*one-way ANOVA test.

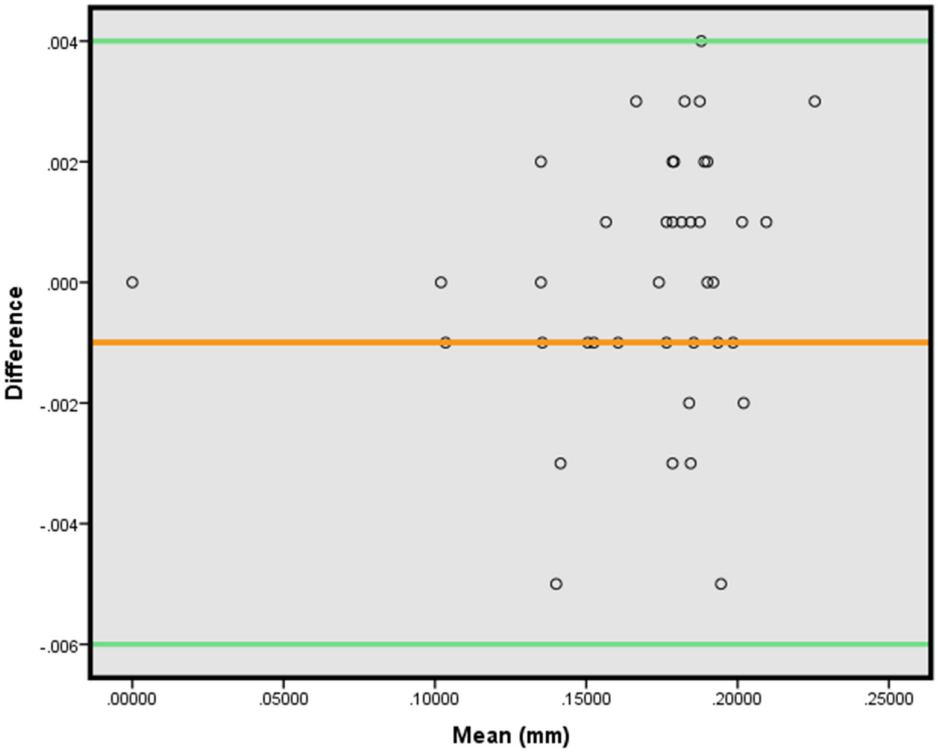

Figure 4: Bland-Altman plot for intra-operator reliability of expected root position formation during two different periods. The X-axis represents the means of the compared measurements, while the Y-axis represents the difference between the compared measurements in (mm). The orange line represents the bias, and the green lines represent the upper and lower limits of agreement.

The current study was done on models instead of people because it is difficult to standardize all confounder factors in patients. Therefore, all findings are due to intervention on the models by the researcher without confounder factors. Moreover, the methodology required two CBCTs of the entire arches, which would be unethical according to the ALARA (As Low As Reasonably Achievable) principle on patients.

The differences between displacement means of the four studied groups were statistically non-significant. It means that the ERP can be assessed with (direct/indirect) bracket bonding and (LACC or LAT oriented) bracket positioning techniques. The results came in agreement with the findings of previous studies[1,3,18-22].

Another ERP approach is that the root position can be expected before the insertion of a temporary anchorage device (TAD). Also, space between roots can be assessed for the insertion of dental implants by this method.

Despite the present and previous studies[1,3,18-22] that showed the ERP setup was accurate to monitor root at any appointment, still, mid-treatment or final radiograph may be needed to assess pathological conditions or root resorptions, because by ERP technique just root position expected virtually without viewing roots and their surrounding tissues like radiographs. However, the most common teeth susceptible to root resorptions are maxillary and mandibular incisors. The clinician can use ERP with periapical radiographs (PA) instead of taking a CBCT scan to monitor these teeth. An effective dose of PA radiograph is <10 µSV, which is lower than the effective dose of a small field of view CBCT scan (5-652 µSV) with a mean of 84 µSV[25]. In the end, although a PA radiograph was taken for susceptible teeth but still the patient exposed to a lesser amount of radiation.

The main limitation of generating an ERP is the high cost of these new technologies like IOS and software. Moreover, pre-treatment CBCT of the patient is required. However, progression in the CBCT technology, IOS, and image processing software may make this approach available for clinical application shortly.

Conclusions

Combining data from CBCT and a digital model, simulation of the root position during orthodontic treatment was statistically validated, so the null hypothesis was accepted. The technique of expecting root position can be equally applied with both techniques of bracket bonding (direct and indirect) and positioning (LACC or LAT) procedures.

This study can be carried out on humans to find whether the result is different in in-vivo compared with in-vitro.

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