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ORIGINAL ARTICLE

Comparison of Bracket Position Accuracy with Different CAD/CAM Indirect Bonding Systems

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ABSTRACT

Objective: To evaluate the accuracy of three different digital bracket positioning systems, comparing vertical, mesiodistal and buccolingual accuracy. **Material and Methods:** The same case was sent to Orapix, Insignia, and Orthocad systems and the brackets were bonded to the malocclusion models. Damon 3 MX brackets were used with all systems and the brackets were bonded to the models with the same bonding protocol and materials. The comparison of the position of each single bracket was made with digital photography, and ImageJ software was used to find the length in pixels and then convert it to hundredths of a mm for vertical, mesiodistal and buccolingual displacement, compared to the setup. **Results:** Insignia System reported the average higher vertical displacement (0.28 mm), compared with the other two appliances (0.22-0.23 mm), and showed the lowest average displacement for the mesiodistal and buccolingual positioning (0.14 and 0.07 mm, respectively). However, these slight bracket positioning variations between these bonding systems were not statistically different ($p>0.05$). **Conclusion:** The three systems analyzed were shown to be accurate in positioning the brackets, and none of them was statistically better.

Keywords: Orthodontics; Orthodontic Brackets; Orthodontics, Corrective.

Introduction

Modern technologies are increasingly widespread on the market that promise an increase in orthodontic treatments' quality and efficiency [1,2]. For example, today it is possible to create an interactive 3D treatment plan from digital models to virtual setup up to assisted positioning.

The literature showed some advantages for orthodontists [3]. There is the possibility in the software of carrying out a diagnostic setup, simulations of virtual extractions [4,5], indirect and direct computer-assisted bonding [6]. There is the possibility to send images and files via e-mail; and the ability to instantly retrieve patient records from a database and view it on a screen instead of having to retrieve them from a physical archive. Economically, orthodontists need less space for the occupation of areas dedicated to the plaster models collection. Digital model cast can be stored indefinitely, and it could be useful for the resolution of the medico-legal problem [7].

Three-dimensional analysis of tooth movements is also possible in multidisciplinary cases [8-10]. It has been verified that the data obtained in the evaluation of dental movements through the superimposition of virtual models are superimposable to those obtained from the cephalometric examination. Furthermore, considering the palatine wrinkles [11,12], as a stable area for the upper arch, it is possible to visualize the dental movements in three dimensions, instead of two-dimensionally, as happens for the superimposition of two cephalometrics.

By digital technologies, the orthodontist can count on virtual setups to make malocclusion treatment more predictable, also considering the force released by the lips [13]. In addition, the setup allows to evaluate the need for extractions, overcorrections, or interproximal reduction and facilitates communication with the patient by showing the risk [14,15] and the benefit of the treatment a priori. However, to date, there is no clarity in the literature on the actual accuracy of the transfer methods adopted by the various systems for the transition from indirect bonding to the patient's arches. As prescribed by the different manufacturers, Insignia and Orthocad used single jigs united in groups (3 per arches) while Orapix used transfer trays in Memosil.

Recently, computer-aided design and computer-aided manufacturing (CAD/CAM) systems have been developed for indirect bonding. These processes involve designing a digital model in a CAD/CAM program to produce a transfer jig. The CAD/CAM transfer jig improves the bonding of the bracket to the target tooth [16-18].

Accurate bracket positioning has a great influence on the result of orthodontic treatment [19,20]. In literature, the articles analyzed the differences between the different methods: direct, traditional indirect and computer-aided indirect bonding. The accuracy is indicative of the repeatability of the positioning of the brackets in the same position on the tooth surface [19,20].

The purpose of this study was to evaluate the accuracy of different digital bracket positioning systems, comparing vertical, mesiodistal, and buccolingual accuracy of bracket positioning.

Material and Methods

Study Design and Sample

This is a comparative study. The test patient was an adult 30.4 years old, showed a permanent dentition, brachyfacial skeletal pattern, molar and canine Class I malocclusion, and the anterior teeth were slightly crowded.

Data Collection

For the test patient, impressions were taken with the "double impression technique" in polyvinyl siloxane and sent to the Orapix (Orapix Co., Ltd, Seoul, Korea), Insignia (Ormco Corporation, Glendora, CA, USA) and Orthocad (Cadent Inc., Carlstadt, NJ, USA) systems. The bonding requirement was standard for all digital systems so as not to have great differences in positioning between one system and another (Figures 1 to 3).

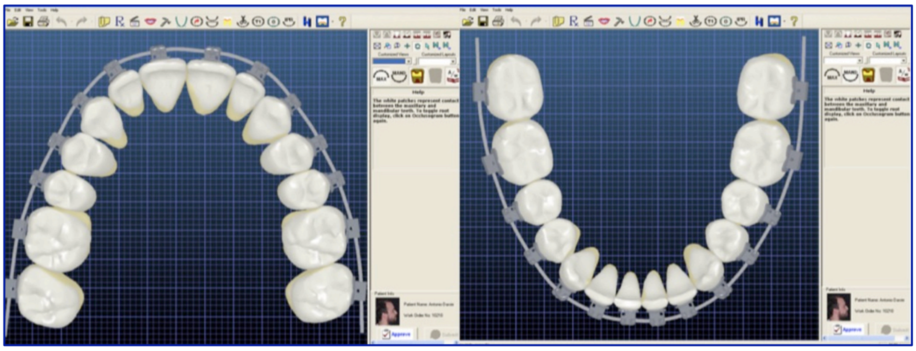

Figure 1. Insignia system.

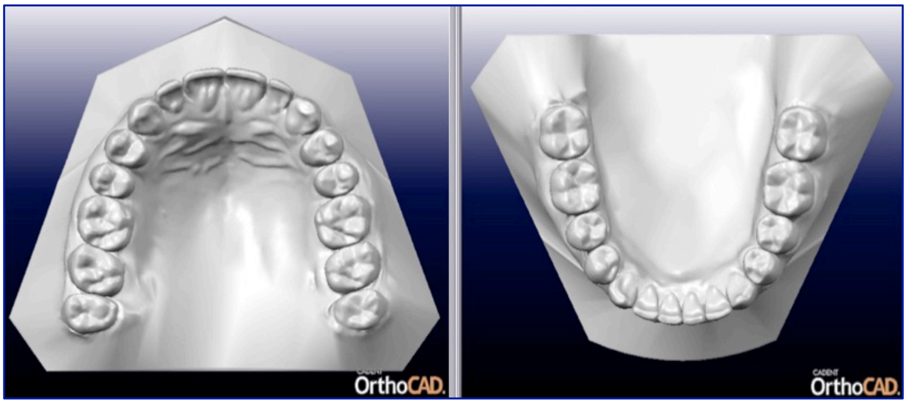

Figure 2. Orthocad system.

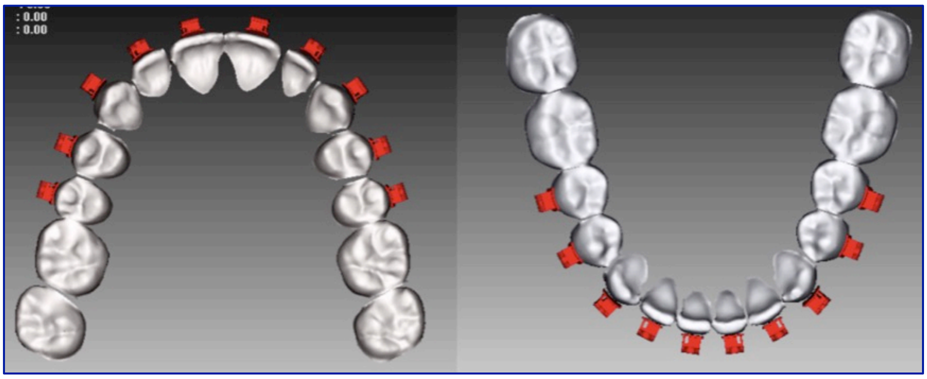

Figure 3. Orapix system.

In any case, the analysis focused on the differences in the positioning of the brackets present between a given system and the application of that system in reality.

The same brackets (Damon 3 MX, Ormco Corporation, Glendora, CA, USA) were used with all systems and were bonded to the models with the same bonding protocol and materials. The transfer bonding trays were similar between the different techniques: Insignia and Orthocad used single jigs united in groups (3 per arches) while Orapix used transfer trays in memosil (Memosil 2, Kulzer GmbH, Hanau, Germany).

The comparison of the position of each single bracket is made with digital photography, which must always be performed in the same position for each view. The model was photographed in occlusal, front, right and left lateral views and in each photo, it will have a millimeter film overlaid to allow to calibrate of the measurements. For this purpose, we used a digital reflex camera with a 105 mm macro lens suitable for intraoral photos. The machine was placed on a stand at the height of 50 cm and fixed with the lens perpendicular to the ground. The settings used were mode A, F32, exposure 1/60 s, distance 0.6 m, Flash yes, ISO 800. A graph paper was placed on the work base on which the references for the feet of the stand are drawn on the sides to be locked in a reproducible position (Figure 4).

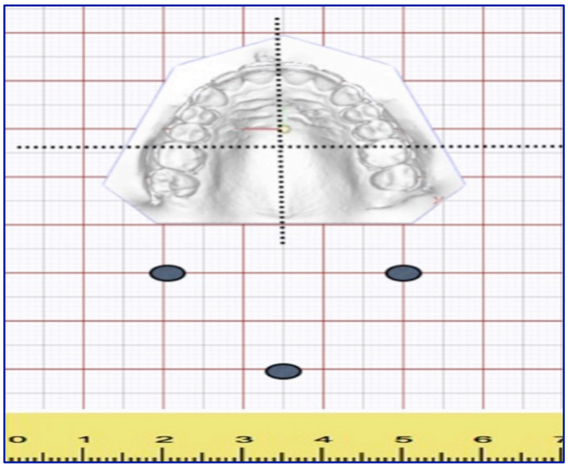

Figure 4. Graph paper on the work base.

Furthermore, two reference axes are traced on the paper: one transverse and one longitudinal in the center of the first. For the occlusal photo, the model is positioned with the median line superimposed on the longitudinal axis of the paper and a line passing through the mesiobuccal cusps of the sixths is superimposed on the transverse line on the paper. For the superior frontal photo, the disto-vestibular cusps are located 2.5 cm from the transverse reference line, and the median line is superimposed on the longitudinal axis of the paper. For the lower front photo, the disto-vestibular cusps are located 1 cm from the transverse reference line and again, the median line is superimposed on the longitudinal axis of the paper.

In an occlusal vision, the measurement of the mesiodistal position of the bracket is calculated as the distance between the line passing through the center of the tooth, found as equidistance from the contact points, and the line parallel to this passing through the center of the surface of the base of the bracket (Figure 5).

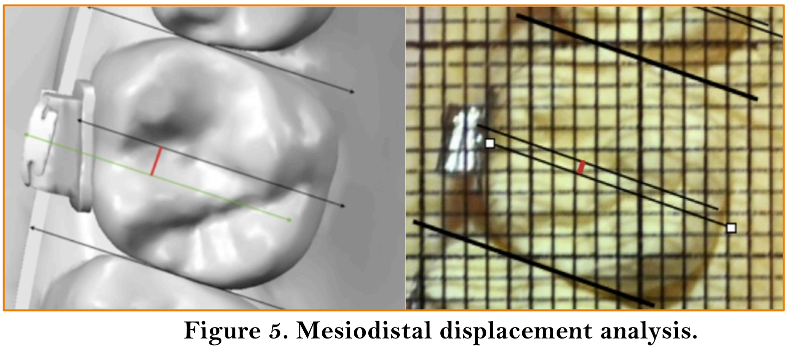

Figure 5. Mesiodistal displacement analysis.

The measurement of the vertical position of the bracket is calculated as the distance between the incisal edge / occlusal edge of the tooth and the upper base of the bracket in front view (Figure 6). The upper base was taken as a reference in both arches because it was not covered by the door of the bracket. The buccolingual measurement is carried out in occlusal view: distance from the center of the buccal surface of the tooth to the surface of the bracket base measured for each tooth (Figure 7). ImageJ software was used to find the length in pixels and then convert it to hundredths of a mm. One thousand one hundred twenty-eight measures relating to three variables were totally analyzed, measuring over two times on 28 teeth. The measurements were made after the transfer of the brackets

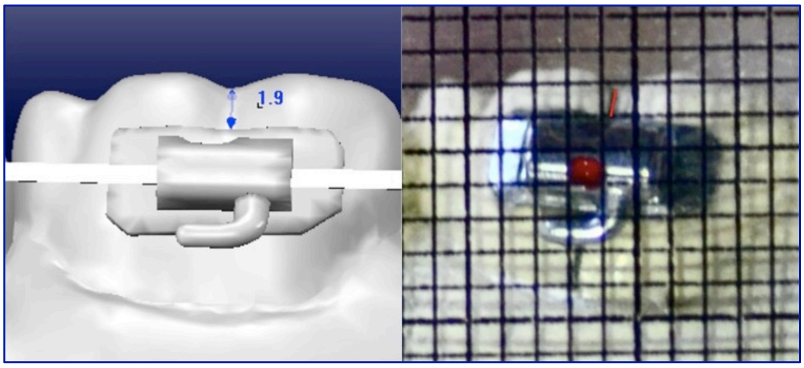

Figure 6. Vertical displacement analysis.

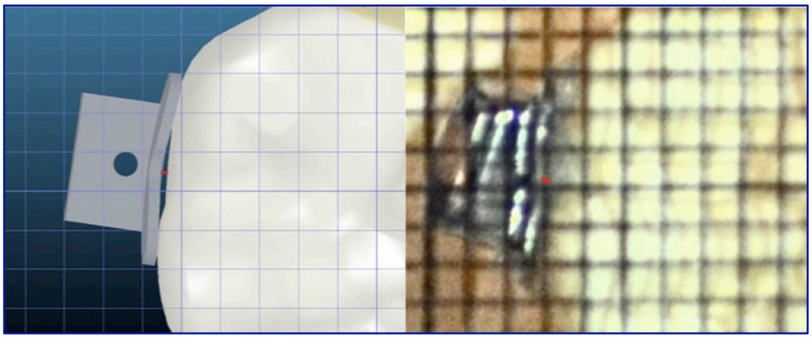

Figure 7. Buccolingual displacement analysis.

Statistical Analysis

The model used allowed us to evaluate how the mask and time affect the level of the measured variable; therefore, the difference in positioning before and after the transfer of the brackets is statistically significant. The analysis of variance (ANOVA), F-Test, and Tukey test were also used. A second operator evaluated the measurement error (replicability). Performing a second systematic detection was necessary to evaluate the reproducibility error with the Dahlberg method, which turned out to be 0.02. Statistical analyzes were performed with SAS 9.2 Software (SAS Institute Inc., North Carolina, USA).

Ethical Clearance

The study design was reviewed and approved by the Ethics Committee of Postgraduated School of Orthodontics of Ferrara University (approval number 7/2015).

Results

The vertical, mesiodistal and buccolingual displacements with statistical data were shown in Tables 1 to 3. Insignia System reported the average higher vertical displacement (0.28 mm), compared with the other two appliances (0.22-0.23 mm), and showed the lowest average displacement for the mesiodistal and buccolingual positioning (0.14 and 0.07 mm, respectively). However, these slight bracket positioning mesiodistal and buccolingual variations between these bonding systems were not statistically different. The average displacements between setups and model bonded were statistically significant ($p<0.05$) only for the vertical measurements.

Table 1. Vertical displacement between setups and models bonded (mm).

Bonding System	N	Avg. Differences	F-Test p-value	SD	Minimum	Maximum	Tukey Group
Insignia	28	0.2817857	<0.01	0.2385613	0.0200000	0.9800000	A
Orthocad	28	0.2346429	<0.01	0.1707604	0.0100000	0.7300000	A
Orapix	28	0.2240000	<0.01	0.1231772	0.0100000	0.4600000	A

Table 2. Mesiodistal displacement between setups and models bonded (mm).

Bonding System	N	Avg Differences	F-Test p-value	SD	Minimum	Maximum	Tukey Group
Insignia	28	0.1460714	0.2143	0.0992318	0	0.3500000	A
Orthocad	28	0.1835714	0.3576	0.1262629	0.0310000	0.4100000	A
Orapix	28	0.1530000	0.2866	0.1002681	0.0200000	0.3800000	A

Table 3. Buccolingual displacement between setups and models bonded (mm).

Bonding System	N	Avg Differences	F-Test p-value	SD	Minimum	Maximum	Tukey Group
Insignia	28	0.0764286	0.0976	0.0595797	0	0.2200000	A
Orthocad	28	0.1257143	0.1423	0.0910608	0	0.2900000	A
Orapix	28	0.1160000	0.1255	0.0705169	0.0200000	0.2400000	A

Discussion

Despite the clinical importance of accurate bracket placement, only a few studies have investigated the extent of errors committed in indirect bonding, not investigating digital systems. Balut et al. [21] evaluated the precision of direct bonding and reported an average vertical error of 0.34 mm. It was described that it was easier for the orthodontist to correctly position the brackets on the lower incisors than on the other teeth. However, the major vertical errors were committed in the positioning of the bracket on the second upper premolar. On the other hand, the major axial errors were committed at the level of the upper incisors and the upper and lower canines. There were no statistically significant differences between the different operators. Consequently, they demonstrated the existence of an intrinsic "human" difficulty in correctly positioning the brackets directly.

Koo et al. [22] compared the precision of indirect and direct bonding and showed that there was no statistically significant difference between the two groups, reporting a mean vertical error of 0.35 mm and a mean horizontal error of 0.19 mm compared to a third group that presented the ideal positioning of the brackets.

This study aimed to evaluate the effective accuracy of 3 digital assisted positioning systems for the brackets on the same patient. The displacements between planned and obtained brackets positions agreed with what is present in international scientific literature.

Hodge et al. [23] performed a randomized clinical study on bracket placement: no statistically significant differences between the two groups reported a mean vertical error of 0.27 mm and a horizontal of 0.11 mm; the errors were greater in the upper arch than in the mandibular. Armstrong et al. [24] investigated the differences in accuracy between two vertical bracket placement methods. The first method consisted of visually identifying the center of the clinical crown (FA Point), while the second measured the distance from the occlusal margin using an altimeter. This second method proved more accurate and reproducible, especially for the anterior sector. There are several bonding methods described in literature [20-25].

Error in the printing of the transfer jig for a bracket would not be excluded after the setup by the 3D digital program. In addition, the jig could not cover the undercut of a bracket, and the elasticity of the jig would be less than that of silicone to make a free gap between the transfer jig and the bracket. These properties of the jig material could influence the accuracy of the bracket position.

Thanks to new digital technologies, today, the orthodontist can count on virtual set-ups that promise to make the treatment of malocclusion more predictable [26]. The set-up allows to evaluate the need for extractions, overcorrections or interproximal reduction and facilitates communication with the patient by showing the result of the treatment a priori [27]. However, to date, there is no clarity in the literature on the actual accuracy of the transfer methods adopted by the various systems for the transition from indirect bonding to the patient's arches.

The purpose of this study was to evaluate the effective accuracy of three digital assisted positioning systems for the brackets on the same patient to remove the inter-individual anatomical variability [28]. The results show no perfect correspondence between the positioning of the brackets in the setup and the transfer on the teeth. However, the differences are small. They may partly depend on the operator, and it is not possible to prefer one of these systems over another regarding the accuracy of the positioning of the brackets.

The use of more advanced software for this analysis could help clarify the slightly incorrect positioning, even if the quality of the final result of the orthodontic case certainly depends more on the setup than on these three transfer systems, all very accurate [29-33]. The results showed similar displacements of bracket positioning between different teeth; in fact, the accuracy of transfer trays systems should not be affected by the tooth anatomy.

Conclusion

Insignia, Orthocad, and Orapix systems are accurate in the bracket positioning methods. The differences in bracket positioning were minimal concerning the planned bracket positions and are statistically significant only for vertical displacements. The vertical displacement measures showed the highest errors in bracket positioning.

Authors' Contributions

PA	iD	https://orcid.org/0000-0002-4020-5065	Conceptualization, Methodology, Investigation, Writing - Original Draft and Writing - Review and Editing.
MT	iD	---	Data Curation and Writing - Review and Editing.
FC	iD	https://orcid.org/0000-0002-4641-2196	Formal Analysis and Writing - Review and Editing.
MP	iD	https://orcid.org/0000-0001-6198-3053	Conceptualization, Formal Analysis, Writing - Original Draft and Writing - Review and Editing.
All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.			

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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