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Research Article

Accuracy of 3DPrinted Windowed Bracket-Positioning Guide Versus Thermoformed Transfer Tray for Orthodontic Indirect Bonding: A Randomized Clinical Trial

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Abstract

Aim: To compare the digital 3d printed window transfer tray and the conventional thermoformed tray regarding the accuracy of transferring the attachments.

Methodology: A randomized clinical trial was performed the two different bonding techniques, 144 attachments were recruited in this study. In the control group, the orthodontic attachments were bonded to working models and scanned with an intraoral scanner to make STL file of the working model. The transfer tray was then fabricated in order to transfer the orthodontic attachments in to the patient's mouth. While in the intervention group, the teeth were scanned with the same intraoral scanner to produce the digital model on which the virtual attachments are placed using the OrthoAnalyzer software. The tray was designed and printed with windows opened gingivally. The attachments were fitted into their positions through the windows of the tray. Then intraoral scanning for both groups was done to obtain STL models after bonding. Superimposition of the pre and post STL models was done using 3Shape OrthoAnalyzer software to measure the angular deviations (tip, torque and rotation).

Results: There was no statistically significant difference between both techniques for overall accuracy of transfer in all angular deviation.

Conclusion: Vacuum formed tray and 3D printed window transfer tray showed comparable degree of accuracy with 3D printed window transfer tray.

Keywords: 3DPrinted Windowed Bracket; Positioning Guide; Thermoformed Transfer Tray

Background

Precise bracket positioning has long been the target of many orthodontists due to its known advantages. It culminates in to best treatment outcome in the shortest time with minimal need for further arch wire bending and bracket repositioning. Many studies have tried to reach a reproducible technique with standard results; however none has discovered the most reliable method because the human factor can't be neglected [1].

The development of technology and the use of digital solutions in dental field have transformed diagnosis and treatment planning from a traditional 2D approach into an advanced 3D technique. Computer-aided design and computer-aided manufacturing (CAD/CAM) have been a focus of dental research since the 1980s to minimize human error in dentistry [2]. The main goal of using CAD/CAM technology into orthodontics can be best summed up as "improving reproducibility, efficiency, and quality of orthodontic treatment. Reviewing the current literature, it was found that 3D printed transfer trays are not profoundly tested clinically. The available studies are only case reports without any comparison between 3D printed design and conventional indirect bonding.

Aim of the Study

The aim of our study was designing a novel transfer digital tray with buccal /labial windows of the exact position of bracket base and 3D printing of this bracket placement guide. Furthermore, this study aims to test the accuracy of this 3D printed transfer tray and compare it to the already established conventionally indirect bonding transfer tray.

Materials and Methods

This prospective study was approved by the Research Ethics Committee of the Faculty of Dentistry, Cairo University. Patient selection for this trial was done in the outpatient clinic of the Department of Orthodontics, Faculty of Dentistry, Cairo University. Eligible patients were enrolled in a consecutive series. Non-syndromic, Class I molar and canine, non- extraction 2-4 mm crowding and spacing cases were included. The sample of this trial included 6 Subjects in need of fixed orthodontic treatment, with a total of number of 144 attachments, this was divided into two groups with 72 attachments for each group. For every patient had a preparatory stage of scaling, polishing and oral hygiene instructions. Full intraoral photographs, study models and panoramic and lateral cephalometric x-rays were taken.

Randomization of the study and sequence generation

This study was a randomized clinical trial, in which there was an intervention group (The 3D printed window transfer tray) and a comparative group (The vacuum formed transfer tray) used to bond orthodontic attachments to the patient's dentition.

An opaque sealed envelope was used for every patient carrying information about either it is a control or intervention. Each patient was then allowed to choose a paper from the sealed envelope. The randomization was performed with a 1:1 ratio of allocation, the sequence was computer generated. The method of randomization was carried out through RANDOM.ORG software.

Intervention group

Intraoral scanning by CEREC Omnicam intraoral scanner (Cerec CAD/CAM intraoral scanner, Sirona, Germany) was done to construct a 3D working model. The STL model was imported to the 3Shape OrthoAnalyzer software (3Shape Company-Copenhagen, Denmark). The orthodontic attachments 0.022*0.028 "Roth prescription (American orthodontics mini master roth 0.22 withhooks 5-5 ver1) were chosen from a wide library containing various types and prescriptions of different orthodontic attachments. Each attachment's position was then modified individually according to the investigator's preference and by the help of the digital calibrations calculated by the software in all dimensions (Figure 1). The master model was opened via 3Shape Appliance Designer software to design the transfer tray by drawing the boundaries along the teeth included inside the tray (Figure 2). After designing the tray and defining its boundaries,it was saved as an STL file ready for 3D printing (Figure 3). Trays were printed using rigid Ortho clear resin. After 3D printing of the tray, the teeth were etched with a 37% phosphoric acid gel for 20 seconds. Each tooth was then rinsed and thoroughly dried until it had a chalky white appearance. A drop of Transbond XT bonding agent (Transbond XT, 3M, Monorovia, CA, USA) was added over the etched surfaces of the teeth. A thin layer of light cured adhesive (3M Unitek, Monorovia, CA, USA)was added to the base of the orthodontic attachments. The orthodontic attachments was placed into tooth surface though the windows of the tray ensuring the attachment base is firmly attached to its tooth surface by gently pushing the attachments against the tooth surface (Figure 4). Then each attachment was light cured with a hand-held light cure device (Woodpecker, iLed light cure, China) for 20 seconds (Figure 5).

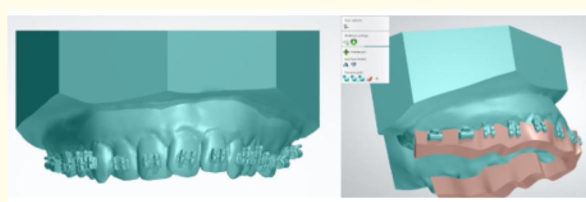


Figure 1 Figure 2

Figure 1 and 2

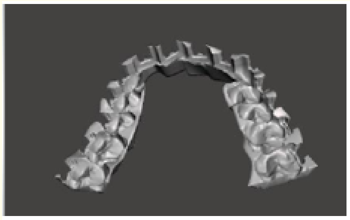


Figure 3

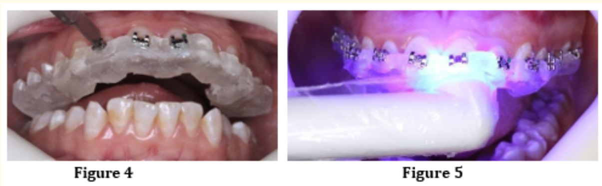


Figure 4 and 5

Removal of the tray was done using a probe through its path of insertion (Figure 6).

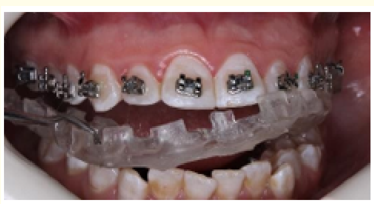


Figure 6

Control group

Accurate alginate impressions (Zhermach Hydrogum system, Alginate Impression Material) were taken for the upper arches in order to make working models for the indirect bonding. The impressions were poured with type-IV extra hard stone (Zhermack Elite rock, type 4 extra hard dental die stone). Using the 0.03-mm black lead pencil, vertical lines were drawn on the cast from the right to left first molars. Using the same pencil, horizontal lines were drawn on the model on molars and bicuspids connecting buccally the mesial and distal marginal ridges. A second horizontal line was drawn buccally using another color lead pencil at the buccal pit of the first molar of one side gingival and parallel to the first line. Using bow divider, the distance between the first and second lines was measured and replicated to all teeth. Thesame orthodontic attachments used in the intervention group were bonded to the working model with a single thin layer of Tacky glue adhesive (Aleene's All Purpose Tacky Glue, USA) (Figure 7) and pressed firmly on the working model to get rid of any excess adhesive material. The orthodontic attachments were then allowed to set for at least 5 minutes and then checked for retention on the cast. Soft vacuum sheet 1 mm thickness (Easy-Vac Gasket Bleaching/Mouth Guard sheets, USA) was vacuum-formed over the model using vacuum forming machine by first heating the vacuum sheet and then was pressed it on the model. The excess material was trimmed away up to 1mm apical to the gingival margin, then, the tray has been cleaned with a clean tooth brush and finally carefully air dried. Bonding procedures were done as in the intervention group.

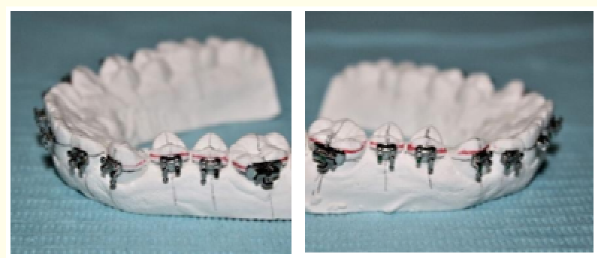


Figure 7

Intraoral scanning

The patients' mouths were scanned with the same intraoral scanner, to obtain the second 3D attachments' relation to the dental arch, with data in STL files. The orthodontic attachments were first sprayed with the intraoral scanning spray and then scanned with the intra-oral scanning camera (Figure 8).

Post clinical stage

The scanned model was saved as STL file format (Figure 9). Now, the pre-operative and the post-operative STL files of the intervention group were ready for superimposition and comparison Using 3Shape Ortho Analyzer software (Figure 10).

Figure 8

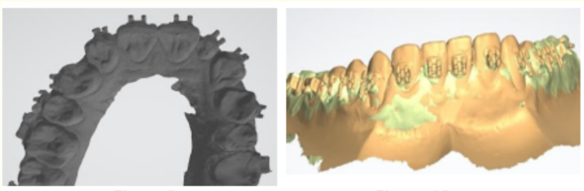


Figure 9 Figure 10

Figure 9 and 10

Assessment of the accuracy outcomes

It was done through Superimposition for intervention and control group: The angular discrepancies were measured as follow: Tip difference from the frontal view of the superimposed scans, Rotational difference from the bottom view of the superimposed scans and Torque difference from the lateral view of the superimposed scans. To measure the tip discrepancy, an imaginary plane was drawn perpendicular to the X axis (Figure 11). A line connecting two wings of each bracket was drawn, this line represented the long axis of the bracket. The angle between the imaginary plane and the long axis of each bracket in the pre-operative (Figure 12) and post-operative (Figure 13) scan was calculated. The angular discrepancy was the difference between these two readings (Figure 14). This procedure was done two times for each bracket; with the line of the long axis connecting two wings each time, and the mean distance was then calculated.

The same steps were done to measure the rotational (Figure 15-18) and torque discrepancies (Figure 19-22).

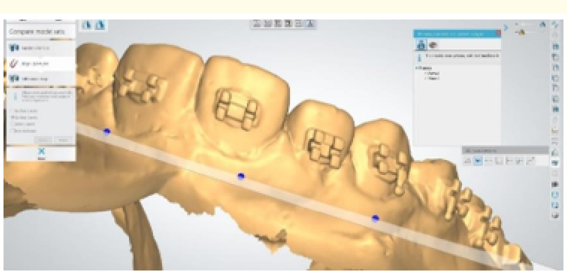
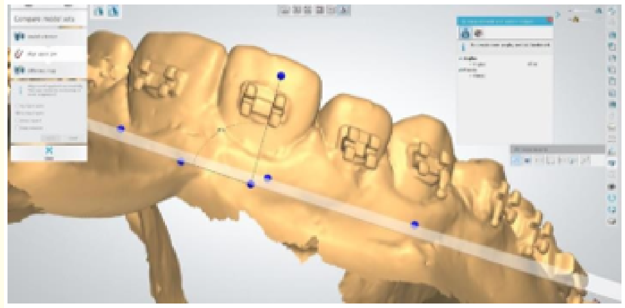


Figure 11



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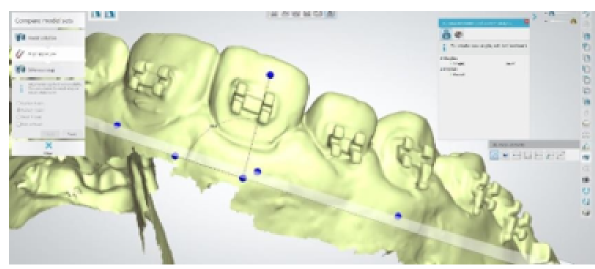

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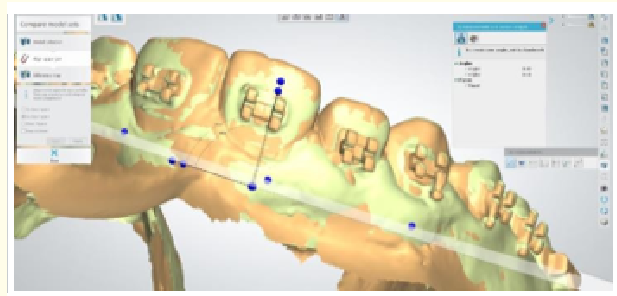

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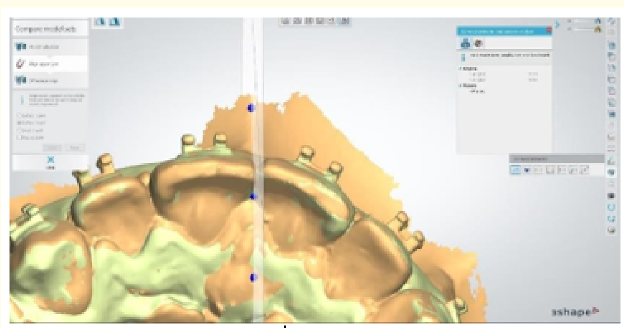

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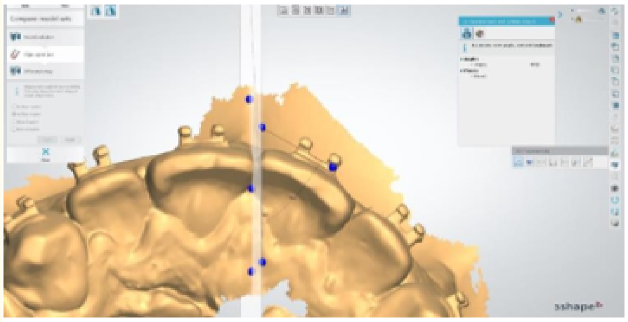

Figure 16

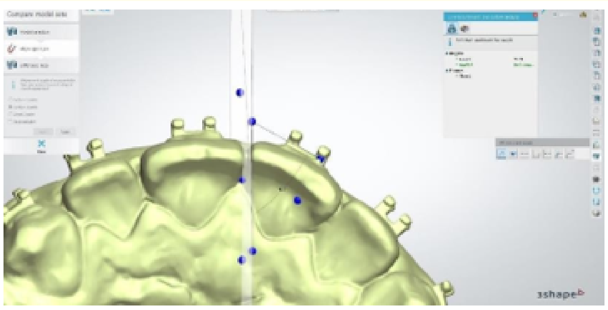

Figure 17

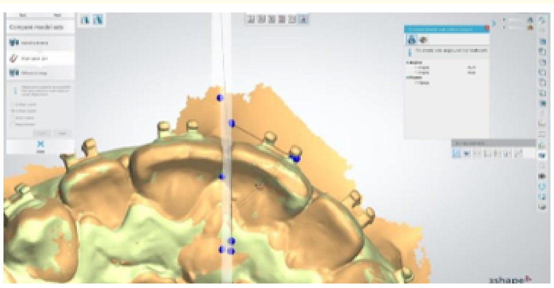

Figure 18

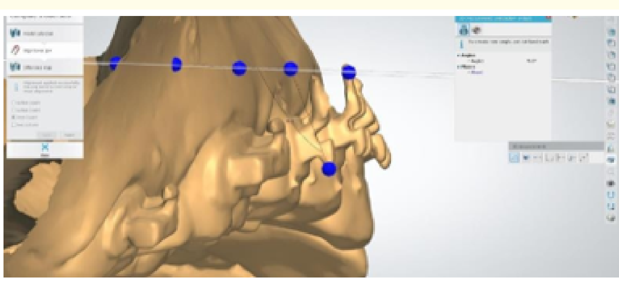

Figure 19

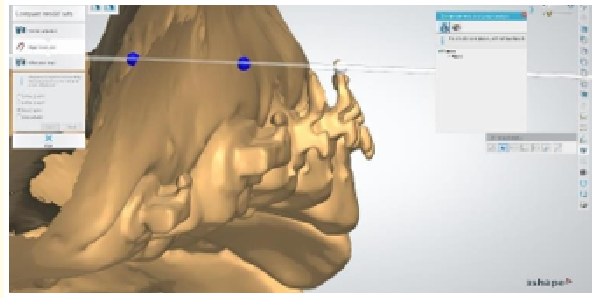

Figure 20

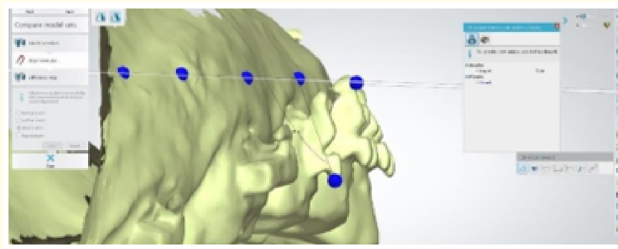

Figure 21

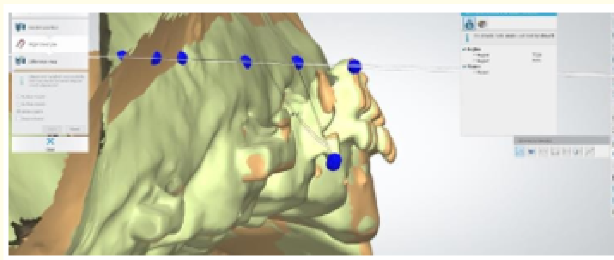

Figure 22

Results

The results of the trial will be presented under the following headings:

1. Data normality (Table 1).
2. Accuracy of transfer of orthodontic attachments between 3D printed window transfer tray and vacuum formed tray in terms of tip (Table 2), torque (Table 3), rotation (Table 4) deviations. Statistical analysis was performed with SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. Qualitative data were presented as counts and percentages. Quantitative Data were presented as means and standard deviation (SD) values. Regarding qualitative data, comparison was performed using Chi square test. On the other hand, data were explored for normality by using Shapiro Wilk Normality test and then independent t test performed for parametric data.

Group		N Group I (Control)	Group	
			Group II (Intervention)	d
Angular Measurements	Tip Difference	144	> 0.05	> 0.05
	Torque Difference	144	> 0.05	> 0.05
	Rotational Difference	144	> 0.05	> 0.05
Failure percentages		144	> 0.05	> 0.05
Chair side time		144	> 0.05	> 0.05

Table 1: Normality exploration of each attachment for both groups.

N: Attachments Count.

Tooth	N	Group I (vacuum formed tray) M ± SD (degrees)	Group II (3D printed window transfer tray) M ± SD (degrees)	Mean Difference in degrees	P-value
1	12	0.45 ± 0.16	1.31 ± 0.23	-0.85	0.001*
2	12	1.12 ± 0.39	0.52 ± 0.16	0.85	0.005*
3	12	1.54 ± 0.23	1.82 ± 0.36	-0.28	0.063
4	12	1.68 ± 0.23	1.91 ± 0.39	-0.23	0.068
5	12	1.63 ± 0.35	0.92 ± 0.24	0.71	0.008*
6	12	1.59 ± 0.31	1.80 ± 0.62	-0.21	0.421
Overall		1.33 ± 0.31	1.38 ± 0.33	-0.05	0.791

Table 2: Means and standard deviations of comparison between the accuracy of the transfer in the tip direction of both types of transfer tray.

N: Attachments Count; M: Mean; SD: Standard Deviation; P: Probability Level; *: Significant Difference.

Tooth	N	Group I (vacuum formed tray) M ± SD (degrees)	Group II (3D printed window transfer tray) M ± SD (degrees)	Mean Difference in degrees	P-value
1	12	0.53 ± 0.18	0.49 ± 0.09	0.04	0.098
2	12	1.10 ± 0.38	0.48 ± 0.16	0.62	0.007*
3	12	0.65 ± 0.28	0.84 ± 0.31	-0. 19	0.204
4	12	0.96 ± 0.29	0.41 ± 0.12	0.55	0.001*
5	12	1.61 ± 0.39	1.36 ± 0.31	0.25	0.171
6	12	1.31 ± 0.43	1.43 ± 0.38	-0.12	0.641
Overall		1.03 ± 0.32	0.83 ± 0.23	0.71	0.149

Table 3: Means and standard deviations of comparison between the accuracy of the transfer in the torque direction of both types of transfer tray.

N: Attachments Count; M: Mean; SD: Standard Deviation; P: Probability Level; *: Significant Difference.

Tooth	N	Group I (vacuum formed tray) M ± SD (degrees)	Group II (3D printed window transfer tray) M ± SD (degrees)	Mean Difference in degrees	P-value
1	12	0.42 ± 0.14	0.37 ± 0.09	0.05	0.091
2	12	1.12 ± 0.16	0.36 ± 0.01	0.76	0.001*
3	12	0.45 ± 0.13	0.72 ± 0.21	-0.27	0.008*
4	12	1.05 ± 0.39	1.21 ± 0.48	-0.16	0.479
5	12	0.61 ± 0.11	1.32 ± 0.28	-0.71	0.001*
6	12	1.40 ± 0.42	1.28 ± 0.60	0.12	0.512
Overall		0.84 ± 0.22	0.88 ± 0.28	-0.04	0.736

Table 4: Means and standard deviations of comparison between the accuracy of the transfer in the rotational direction of both types of transfer tray.

N: Attachments Count; M: Mean; SD: Standard Deviation; P: Probability Level; *: Significant Difference.

Discussion

Indirect bonding techniques have been developed to aid the orthodontist in placing the brackets accurately and to save the chair time. "It should take no longer than twenty minutes to complete a full strap-up in the mouth in both arches, including second molars if desired" as was stated by Silverman and Cohen [3]. The indirect bonding technique allows better three-dimensional visualization of tooth position and, as a result, greater accuracy while positioning orthodontic attachments. Precise bracket positioning culminates in to best treatment outcome in the shortest time with minimal need for further arch wire bending and bracket repositioning. Moreover, the accompanying orthodontic complications such as white spot lesions and root resorption could be avoided. This was emphasized by Hodge., *et al*. [4] who reported a significant reduction in the envelope of error using indirect bonding. With the evolution of technology and the use of digital solutions in dental field, the use of digital models in diagnosis and treatment planning has been a routine clinical procedure due to ease of storage, longevity and comparable accuracy to the plaster models which is expected to be replaced by digital study models.

Spitz., *et al*. [5] in 2018 described a new method of preparing trays for indirect bracket bonding using computer-aided technology to design the individualized trays, which were produced with a rapid prototyping procedure. This method included virtual placement of the attachments on the digital study models using special software, then this software fabricated a virtual transfer tray on the digital model. The tray was fabricated through 3D printing process in which the attachments placed to be bonded later on. So, this eliminated several clinical and laboratory steps including taking primary impressions, pouring them with plaster, trimming the models, placing the attachment in their positions using glue or bonding agents and finally fabricating the thermoformed tray. This procedure was claimed to take the indirect procedure to a whole new level. Since the study of Spitz., *et al.* [5] in 2018, very limited studies evolved which evaluate the accuracy of indirect bonding trays as well as 3D printed trays. Most of these studies were *in vitro* studies, with the exception of one *in vivo* study which was carried out by Grunheid., *et al.* [6] where a CBCT was used to scan the models and polyvinyl siloxane was used as a transfer tray. To our knowledge, no studies are available in the literature comparing between conventional and 3D printed indirect bonding trays.

So, the aim of this study was to evaluate and compare the accuracy of the 3D printed window transfer tray with the thermoformed tray.

Regarding the results of the present study, it was essential to highlight the statistical findings of the different outcomes of the current study and to compare them to the findings of similar studies in the previous literature. For angular measurements calculation, deviations along the X, Y and Z axes were recorded for each wing of all attachments. Any deviation in the attachment position refers to the positioning of the attachment itself. For example, a value of 0.1 degree in a certain plane would reflect that the bracket was bonded 0.1 degree away from the position it was originally intended based on the working or the virtual models. Regarding the angular measurements, tip, torque and rotation, they were within the 2 degrees limit defined by Grunheid., *et al* [6].

Regarding the tip deviation in the present study, was no statistically significant difference between 3D printed window tray and the vacuum formed tray techniques (1.38 degrees and 1.33 degrees) respectively. These results ware comparable with the tip results of Grunheid., *et al*. [6] that was (1.11 degree) tip discrepancy.

Regarding the torque deviation in the present study, there was no statistically significant difference between 3D printed window tray and the vacuum formed tray techniques (0.83 degrees and 1.03 degrees) respectively. However, Grunheid., *et al*. [6] showed higher torque deviation mean of (1.31) degree.

Regarding the rotational deviation in the present study, both indirect bonding techniques were not significantly different for 3D printed window tray and the vacuum formed tray techniques (0.88 and 0.84 degrees) respectively. These results were similar to Grunheid., *et al*. [6] which revealed (0.94) degree mean rotational deviation than normal.

There was no directional bias in the angular deviations of 3D printed window tray (intervention group) and vacuum formed tray (control group). Also,in Grunheid., *et al*. [6] study, the rotational deviations were nearly equal in the indirect bondingtechnique.

The overall findings of this study revealed that the 3D printed window tray and vacuum formed tray appeared to be accurate with insignificant difference between them. Although the accuracy of both techniques was comparable.

Conclusion

Vacuum formed tray and 3D printed window transfer tray showed comparable degree of accuracy with no statistically significant difference between two techniques regarding tip, torque and rotational angular deviations.

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