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Evaluation of Accuracy of 3DPrinted Windowed Bracket- Positioning Guide Compared To 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, bond failure and chair side time.**Methodology:** A randomized controlled trial was performed the two different bonding techniques, 6 subjects were recruited in this study with 144 attachments. 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 linear deviations (mesio-distal, occluso-gingival and bucco-lingual) **Results:** There was no statistically significant difference between both techniques for overall accuracy of transfer in all linear deviation except for bucco-lingual linear deviation which revealed higher accuracy of transfer for 3D printed technique than vacuum

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

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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, furthermore it minimizes the need for tooth etching, rebonding and therefore it lowers white spot lesions.

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.

So 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.

Material & 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 & 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 intra-oral photographs, study models and panoramic and lateral cephalometric x-rays were taken.

Intervention group:

Intraoral scanning by CEREC Omnicam intraoral scanner was done to capture the initial position of the teeth and to construct a 3D working model. The STL model was imported to the 3Shape OrthoAnalyzer software, and then trimmed to imitate the stone model. The teeth were then segmented from the cast by drawing the borders of the crowns and the long axes of all teeth. The orthodontic attachments (0.022*0.028 "Roth prescription) 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 (figure3). 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 ppearance. A drop of Transbond XT bonding agent was added over the etched surfaces of the teeth. A thin layer of light cured adhesive 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 for 20 seconds (figure 5). Removal of the tray was done using a probe through its path of insertion (figure 6).

Fig.1

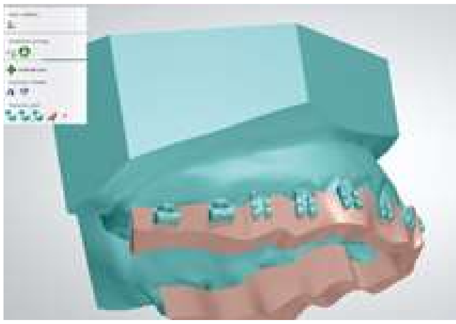

fig.2

fig.3

Fig.4

fig.5

fig.6

Control group:

Accurate alginate impressions 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. The casts were then trimmed enough to allow for good visualization of the teeth and for fabricating the vacuum formed transfer tray later.

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.

The same orthodontic attachments used in the intervention group (0.022*0.028 “Roth prescription) were bonded to the working model with the slots centered on the black horizontal and vertical reference lines with a single thin layer of Tacky glue adhesive (figure 4) and pressed firmly on the working model to get rid of any excess adhesive material. Any chips or remnants of glue were removed with an explorer while the attachments were being set. 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 was vacuum-formed over the model using vacuum forming machine by first heating the vacuum sheet and then pressing 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.

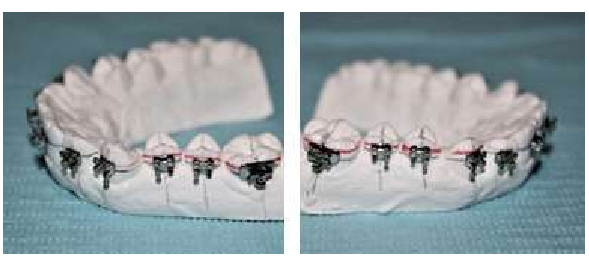

Fig. 7

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).

Fig.8

fig.9

fig.10

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 mesiodistal (Table 2), occlusogingival (Table 3), buccolingual (Table 4) deviations.

3. Inter-observer & Intra-observer Reliability (Table 5 & 6).

The statistical analysis was performed by specialized statistician using IBM SPSS Statistics Version 20 for Windows.

Table (1): Normality Exploration of Each Attachment for Both Groups:

		N	Group	
			Group I (Control)	Group II (Intervention)
Linear Measurements	Mesio-distal Deviation	144	>0.05	>0.05
	Occluso-gingival Deviation	144	>0.05	>0.05
	Bucco-lingual Deviation	144	>0.05	>0.05

N: Attachments Count.

Table (2): Percentages of mesial and distal deviation in group I and II:

	Mesial	Distal	P-value
Group I	45%	55%	0.631
Group II	48%	52%	0.847
P-value	0.885	0.381	

Table (3): Percentages of occlusal and gingival deviation in group I and II:

	Occlusal	Gingival	P-value
Group I	80%	20%	0.004
Group II	47%	53 %	0.337
P-value	0.102	0.381	

Table 4: Percentages of Buccal and Lingual deviations in group I and II:

	Buccal- out	Lingual- in	P-value
Group I	85%	15%	0.008
Group II	60 %	40 %	0.335
P-value	0.107	0.110	

Table (5): Inter-observer reliability of linear measurements in both groups:

		Intra-observer reliability	Group I	Group II
-Linear measurements	Mesiodistal	1	0.96	0.95
		2	0.98	0.97
		3	0.97	0.98
		4	0.94	0.95
		5	0.96	0.96
		6	0.97	0.94
	Occlusogingival	1	0.93	0.95
		2	0.94	0.94
		3	0.98	0.95
		4	0.96	0.94
		5	0.97	0.92
		6	0.98	0.91
	Buccolingual	1	0.99	0.82
		2	0.93	0.95
		3	0.98	0.96
		4	0.97	0.94
		5	0.96	0.97
		6	0.94	0.95

≥ 0.5 (reliable=agreement).

Table (6): Intra-observer reliability of linear measurements in both groups:

		Intra-observer reliability	Group I	Group II
Linear measurements	Mesiodistal	1	0.94	0.95
		2	0.95	0.93
		3	0.91	0.94
		4	0.86	0.91
		5	0.93	0.95
		6	0.91	0.96
	Occlusogingival	1	0.96	0.95
		2	0.97	0.95
		3	0.95	0.91
		4	0.98	0.92
		5	0.96	0.94
		6	0.96	0.95
	Buccolingual	1	0.97	0.89
		2	0.94	0.96
		3	0.97	0.88
		4	0.97	0.86
		5	0.96	0.99
		6	0.98	0.96

≥ 0.5 (reliable=agreement).

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 al4randomized comparison of 2 different methods of bracket placement. SettingQueens Hospital, Burton upon Trent, UK between February and May 2001.Materials and methodTwenty-six consecutive patients requiring upper and lower MBT? pre-adjusted Edgewise appliances had their labial segments bonded directly or indirectly according to a split mouth system of allocation. Before and after bond-up all brackets were photographed and measured from tracings to determine positional differences from the ideal.ResultsUsing ANOVA (General Linear Model 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 al5 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 al5 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 linear 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 mm in a certain plane would reflect that the bracket was bonded 0.1 mm away from the position it was originally intended based on the working or the virtual models. Comparing the present results with other studies, it was found that all linear measurement deviation of the present study in both groups agreed with the +/- 0.5 mm designated accepted range of Grunheid et al.6directional bias, and frequency of bracket positioning errors caused by the transfer of brackets from a dental cast to the patient's dentition in a clinical setting.

MATERIALS AND METHODS: A total of 136 brackets were evaluated. The brackets were placed on dental casts and scanned using cone beam computed tomography (CBCT

Regarding the mesio-distal deviation in the present study, was no statistically significant difference between 3D printed window tray and the vacuum formed tray techniques (0.11mm and 0.08mm) respectively. These results were comparable with the mesio-distal results of **Wendl et al.**[7] who used photographic superimposition and three-dimensional (3D) measurement of the bracket positions on the working models using a 3D laser scan. He found mesiodistal deviations of (0.15 mm). Comparing the accuracy of bracket placement using photographs and calipers, **Koo et al**[8] found comparable results with the present study showing the mesio-distal measurements of (0.18 mm). Regarding the occlusogingival deviation in the present study, was no statistically significant difference between 3D printed window tray and the vacuum formed tray techniques(0.23mm and 0.14mm) respectively. These results ware comparable with the occlusogingval results of **Koo et al**[8] that was (0.31 mm) and **Wendl et al.** [7] that was (0.17 mm). Regarding the buccolingual deviation in the present study, 3D printed window tray showed higher statistically significant accuracy than vacuum formed tray techniques (0.06, 0.10 mm) respectively. **Wendl et al.** [7] found bucco-lingual deviation of (0.19mm) which was higher than the results of 3D printed technique of the present study and comparable to the results of the conventional indirect bonding of the present study. The significant difference in bucco-lingual deviation might be due to uneven thickness of adhesive on the attachment meshwork and the uneven finger pressure during the clinical indirect bonding procedure in control group. While this cause was absent in window 3D printed tray that had an even amount of adhesive and giving the capability to remove the excess adhesives around the attachment base with even pressure to the attachment base. On the contrary, **Schmid et al.**[9] revealed lower deviation in linear measurements for their indirect bonding method (0.04 mm, 0.04 mm, 0.1 mm) as means for the mesio-distal, bucco-lingual and occluso-gingival discrepancies respectively. However, this difference could be clarified by their study design that was in-vitro as well the exclusions of molars from his study.

Conclusions: Vacuum formed tray and 3D printed window transfer tray showed comparable degree of accuracy with 3D printed window transfer tray regarding the mesio-distal, occlusogingival linear deviation, while Vacuum formed tray technique proved to be less accurate than 3D printed technique regarding the bucco-lingual linear deviation for almost all attachments.

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