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Accuracy of Computer-Aided Full Tray vs Computer-Aided Sectional Tray in Indirect Bonding of Orthodontic Brackets; A Randomized Clinical Trial

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Aim: This study was conducted to determine the accuracy of computer-aided full tray vs computer-aided sectional tray in indirect bonding of orthodontic brackets.

Materials and Methods: Twenty patients (10 in each group) with mild to moderate crowding, requiring orthodontic treatment with full set of permanent teeth except for third molars, were chosen for this study. A total of 400 brackets were used for both groups. Similar bracket type and bonding material was used for both groups. The accuracy of bracket transfer was evaluated using GOM software.

Results: pre-transfer and post-transfer bracket positions showing that both transfer methods were accurate in reproducing the pretransfer bracket position onto the patient's dentition in vivo at a clinically acceptable level, however sectional computer aided tray revealed better results as there was a statistically significant difference between the two groups in all dimensions ($p<0.001$) except occlusogingival dimension ($p>0.05$).

Conclusions: Both Computer-aided indirect bonding transfer methods can be used with confidence as it is accurate and within the clinically accepted limits. Sectional computer aided indirect bonding method revealed better results in all dimensions as it had better control, better tray seating and more accurate transfer and can be used in cases with mild crowding. Although transfer errors were mainly in occlusogingival dimension towards gingival and in buccolingual towards buccal direction, still errors were within clinically acceptable limits.

Keywords: accuracy, digital, indirect bonding, 3D printing, transfer tray.

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Introduction

Orthodontists have been always searching for new methods simplifying their maneuver and providing comfort for the patient. Proper bracket placement is important to obtain maximum benefits from fixed orthodontic appliances, facilitating final treatment phases and leading to an optimal occlusion. In 1970s, Silverman [1] first proposed indirect bonding concept .In this technique, brackets were first placed on model . Those brackets were transferred to the patient using transfer tray. However, this procedure was complicated and limited by the materials as well as laboratory process. Today, the bracket position accuracy is becoming more challenging and indirect bonding is becoming more popular than before by solving the visibility issues, reducing clinic time and improving patient satisfaction.[2]. The stage of bracket transfer is important to obtain accurate positioning in indirect bonding and depending on orthodontist skills, tray material properties and different technical and laboratory processes. As the technology advances, a series of digital indirect bonding systems[3,4] allowed orthodontists to simulate teeth aligning , bracket positioning, designing and printing 3D customized trays.[5,6] In this article, indirect bonding technique was digitalized by 3Shape software and the accuracy of computer aided trays was investigated.

Materials and Methods

This trial was approved by the ethics committee at the Faculty of Dentistry Ain-Shams University. Patient selection was done from the outpatient clinic of the Orthodontic Department, Faculty of dentistry, Ain Shams University. A total of 20 patients were planned to receive indirect bonding during the treatment planning phase. All permanent teeth present and erupted except for the third molars, no previous orthodontic treatment, No history of systemic disease affecting bone or teeth, Patients with normal/increased overjet. Patients excluded those who were having medical problems affecting tooth movement (e.g., osteoporosis, bisphosphonate therapy, etc...). Any dental pathology affecting enamel surface, severe crowding preventing proper bracket placement on the labial/buccal tooth surface, patients having bad oral hygiene, patients had extractions before bonding or actively erupting teeth & root resorption.

Patients were randomly chosen using computer software to either computer aided complete tray or computer aided sectional tray groups. Full set of orthodontic records were taken for every patient as part of the routine procedure. Orthodontic model scan and virtual bracket positioning: Stone casts were scanned using 3-shape R-750 scanner 3shape A/S. Copenhagen, Denmark) in the Orthodontic Digital Center at Faculty of Dentistry, Ain-Shams University. Then teeth segmentation, and bracket positioning were done using 3shape ortho analyzer software. Indirect bonding tray design was performed using appliance designer module in the 3shape software.

Tray design & 3D printing: For complete computer aided group one tray for each arch & for sectional computer aided group three sectional trays were designed for each arch (two for posterior segment and one for anterior segment) ,the trays for both complete & sectional groups were designed as a double shell tray, for the first shell, spline was drawn from the first molar to first molar and extended palatally to cover half the palatal surface of each tooth, and buccally covering the whole bracket & its thickness was 1mm. The second shell designed over the first one having the same extensions except for the buccal extension which covered only the occlusal wings & its thickness was 1.5mm. Both shells are then combined creating the final IDB shell which was saved as an STL file. The STL files were sent to a digital orthodontic lab and printed using Next Dent 5100 3D printer.

Clinical steps: The indirect bonding trays were loaded with 0.022-inch pre-adjusted edgewise discovery brackets with Roth prescription ready to be bonded, then the tray was removed cautiously lingually then labially. Remaining excess composite was then removed using 12 flutes finishing carbide bur and a high speed contra angle hand piece. Then indirect bonding procedure completed and patient's teeth were scanned with Trios intraoral 3shape scanner

Methods of data collection: For both computer-aided groups the bracket transfer master model from appliance designer module from 3shape Appliance designer, 3shape as pre-transfer record, Post-transfer record was obtained by intra-oral scanning the patient directly after bonding using Trios intraoral scanner, 3shape mages obtained from intraoral scanner were saved in (STL) format. GOM inspect software was used to prepare and superimpose the scans of each pretransfer and post-transfer model. Best-fit algorithm was used for the surface area of the models, a more even distributed colors indicates good match, while isolated colors indicated poor match. Then, x, y, and z-axis were manually placed for each bracket. The mesiodistal dimension was represented by x-axis, the buccolingual dimension was represented by y-axis and finally the occlusogingival dimension was represented by z-axis. Differences in pre-transfer and post-transfer bracket positions were measured in six dimensions.

Statistical Analysis:

Descriptive statistics were measured for the following measurements (Mesio-distal, Occlusogingival, Buccolingual, Rotation, Tip, Torque) for both the raw data and the absolute values, histograms were plotted for each of the six dimensions. Discrepancy values between the complete and sectional tray methods were compared using dependent t-test on the mean of the absolute values (α=0.05). Statistical analysis was done using SPSS 25 (IBM SPSS, Armonk, NY, USA). Bracket position discrepancy between both groups was determined if there was any significant difference using dependent t-test.

Results

There was significant difference between two groups in all dimensions (p<0.001) except occlusogingival dimension (p>0.05) Table 1.

Table (1) T-test for Computer complete vs. computer sectional groups

Measurement	Complete		Sectional		Paired Differences				p-value
					Mean	SD	95% Confidence Interval of the Difference		
	Mean	SD	Mean	SD			Lower	Upper	
BUCCOLINGUAL BL (LINEAR)	0.21	0.20	0.18	0.19	0.03	0.10	0.02	0.05	<0.001*
MESIODISTAL MD (LINEAR)	0.12	0.13	0.11	0.16	0.03	0.10	0.02	0.05	<0.001*
OCCLUSOGINGIVAL OG (LINEAR)	0.22	0.19	0.19	0.18	0.01	0.13	-0.01	0.03	0.224 NS
Rotation (Angular)	1.35	1.15	1.20	1.08	0.13	0.27	0.09	0.17	<0.001*
Tip (Angular)	1.52	1.20	1.38	1.14	0.14	0.28	0.10	0.18	<0.001*
Torque (Angular)	1.34	1.05	1.21	0.97	0.13	0.28	0.09	0.17	<0.001*

Directional patterns of error:

Histograms were plotted to show the errors direction detected for each of the six dimensions (figure 1-6).

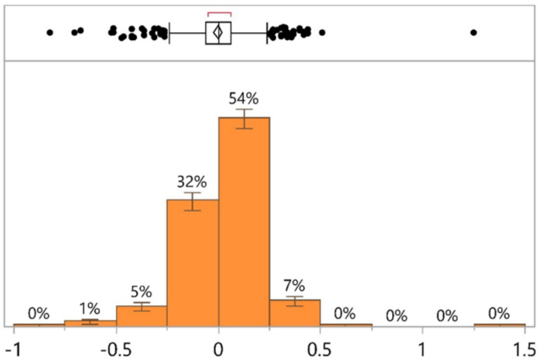

Figure 1: For mesiodistal discrepancy: mesial translation represented by negative values and vice versa. The data is not skewed in either direction.

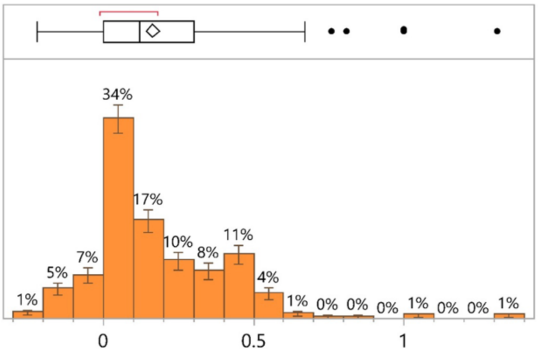

Figure 2: For buccolingual discrepancy: lingual translation represented by negative values vice versa. The data is positively skewed towards the buccal.

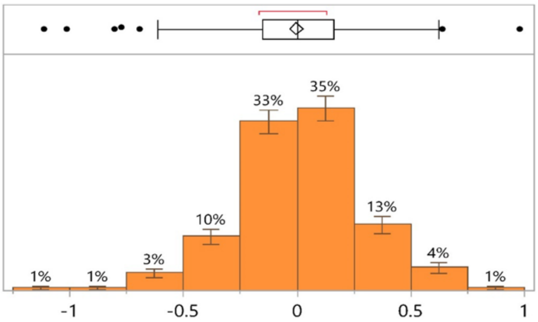

Figure 3: For occlusogingival discrepancy: occlusal translation represented by negative values and vice versa. The data is not skewed in either direction.

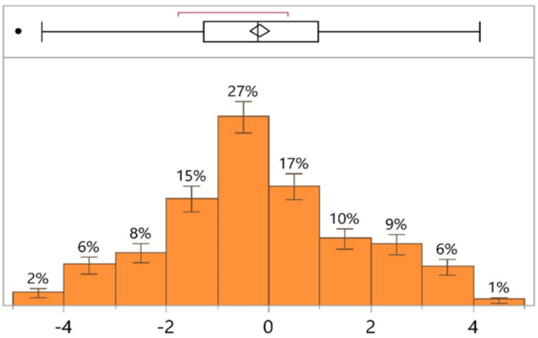

Figure 4: For tip discrepancy: mesial tip represented by negative values and vice versa. The data is not skewed in either direction.

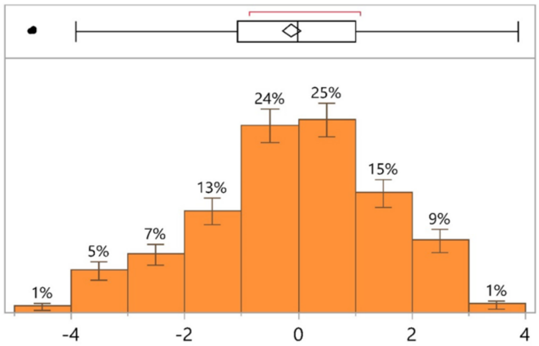

Figure 5: For torque discrepancy: labial crown torque represented by negative values and vice versa. The data is not skewed in either direction.

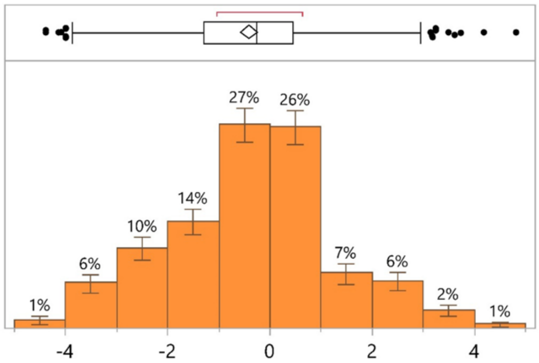

Figure 6: For rotation discrepancy: mesial rotation represented by negative values and vice versa. The data is not skewed in either direction.

Discussion

The primary goal of indirect bonding is proper bracket placement to effectively express the built-in prescriptions to obtain maximum potential of the straight-wire orthodontic appliance & better treatment results, this was reported by Alrbata R (2017)[7]. Bracket positioning is at risk of inaccuracy not only between different clinicians but also between different areas bonded by the same operator, moreover the reliability, time saving and decreased saliva contamination ,which are considered advantages of indirect bonding compared to the direct bracket bonding system as reported by Taneva E [8] & Kalra in 2018[9] .Hodge

TM[10] (2004) and Guenthner TA[11] (2007), revealed that the IDB technique is a good alternative to direct orthodontic bracket positioning reducing clinical stress and chair-time. Moreover, computer aided indirect bracket placement adds more accuracy and ease as well as reducing lab time confirmed by Oliveira NS et al [12] in 2019.This article aimed to determine bracket positioning accuracy indirectly using either complete or sectional computer aided trays to overcome drawbacks associated with traditional indirect bracket positioning techniques such as the need of a double set of impressions consuming more chair time, increasing manufacturing steps causing brackets movement, causing bracket base contamination as well as long learning curve needed and the issue of adhesion and finally, the need for manual undercut block out affecting bracket retention to tray. [13]Twenty participants (10 in each group) were included in this study with ages ranging from 18-35 with full permanent dentition, to ensure eruption and complete root formation. Participants who had extractions before bonding or actively erupting teeth were excluded as there would be risk of tooth position changes that might have occurred between impression time and bonding time as described by Kjaer I(2014)[14]. Severe crowding cases in which precise bracket positions were concealed by improper tray seating were excluded. We excluded patients who had previous orthodontic treatment to ensure bonding to virgin enamel to reduce bonding failure rate. Cases with hypoplastic or demineralized enamel were also excluded to ensure optimum bond strength. To minimize the number of variables, patients with severe attrition, chipped teeth, fractured teeth, root resorption were also excluded. Patients eligible for this study were randomly assigned using computer software generating random number sequence to avoid allocation bias. 3Shape R-750 desktop scanner was used in this study to obtain virtual study models due to its availability in the Digital Orthodontic Center in Ain shams University , its ease of use, reduced cast scanning time, reliability in agreement with LS Lemos[15] (2019). In 2019, Layman[16], Yue Zhang[17] (2020) & Niu Y et al.[18] (2021) used 3Shape software which is offering study model analysis and treatment planning and simplified workflow starting from teeth segmentation till precise bracket placement as well. To assure perfect bracket positioning in relation to the occlusion and marginal ridge alignment, bracket placement was done as recommended by Larry White[19]. Dentaurum discovery brackets with Roth prescription were chosen in concurrence with Supple J [20](2021) due to its availability in the market and good laser marked anatomically contoured bases making identification and adaptation easier. Slot size 0.22 inch was used in this study to ensures closure of spaces and teeth retraction on a suitable heavy wire with the least amount of friction and thus minimizing anchorage loss possibility and this was concurrent with El-Angbawi et al[21], Dresher[22], Fourie[23], Iluru R [24] Appliance designer was used in transfer tray designing, then the indirect bonding tray was printed, making the indirect bonding procedure easier and faster with the least technical steps. Parameters for bracket transfer master model were set to provide maximum retention for the brackets in the transfer tray allowing tray flexibility during insertion and removal without risk of the brackets debonding on removal. Less space designed between the bracket and the tray offers better retention and accuracy, making the tray more difficult to be removed, whereas more space affects the retention and accuracy negatively. Single layer IBT showed cracks and tray tearing during seating, so double layer IBT design was used with different extensions for both shells offering optimum rigidity for the occlusal part without affecting the flexibility needed for the gingival part covering brackets so that brackets can fit well and the tray can be easily removed after bonding, Lingual extensions were covering nearly half the lingual surface of each tooth to offer retention without difficult tray removal and for easier excess composite removal and this design was consistent with Balut et al [25] (2020)

Nexdent manufacturer[26] claimed that NexDent Ortho IBT printing material can be used due to its flexible characteristics of the printed trays, orthodontist can place all the brackets at once, saving chair time. Christensen L in 2018 [27] reported that it showed excellent stability and sufficient flexibility needed to cover the whole bracket gaining better bracket-tray retention. Nexdent 3D printer was utilized due to its compatibility with the IBT material. This professional 3D printer uses digital light processing (DLP) technology using a LED light source to cure liquid resin as well as its compatibility with many resins with different colors and physical properties, this was reported by Sherman SL [28] (2020). The tray was seated in a perpendicular insertion direction to the arch as previously set on the software. Then it was removed from the lingual side then buccal to reduce shear forces on the brackets. TRIOS intraoral scanner[29] was used for its proven and higher accuracy compared to conventional impression & system had precision 0.8 to 1.2 um.

Three-dimensional inspection and both angular/linear measurements were done by GOM Inspect 2019 software presenting data with an accuracy and precision of up to 1 µm, creating a local best-fit so that pre-transfer and post-transfer scans could be superimposed accurately. The superimposition of the 'before' and 'after' models was planned to demonstrate the angular and linear transfer accuracy of two indirect bracket bonding methods, this was consistent with many studies conducted by Gyllenhaal K[30] (2021). Linear differences of 0.5 mm and angular differences of 2 degrees were considered clinically acceptable . These limits were using the American Board of Orthodontics objective grading system.[31] For linear measurements both groups didn't show statistically significant difference mesiodistally, while occlusogingivally both groups showed statistically significant difference towards gingival dimension especially complete trays ,they related this to indirect bonding tray being ''stretched" during clinical bonding, and buccolingually both groups showed statistically significant difference towards buccal, which was attributed to improper tray seating which increased the thickness between bracket base and the tooth surface. For angular measurements, for torque, both groups showed statistically significant difference directed towards lingual crown, while for tip, both groups didn't show statistically significant difference and for rotation, both groups showed statistically significant rotation of facial surface towards mesial direction. Although statistical significance exists, they did not exceed the clinical significance level chosen according to ABO grading system (±0.5mm and ±2°) for any of the six dimensions measured.[32] Our data revealed that both groups had better linear control than angular control of brackets, angular dimensions were generally less accurate than the linear dimensions in which Torque showed the worst transfer accuracies of all angular dimensions. Both groups, showed that both transfer methods were accurate in reproducing the pretransfer bracket position at a clinically acceptable level, however sectional computer aided tray revealed better results as there was a statistically significant difference between two groups in all dimensions ($p<0.001$) except occlusogingival dimension ($p>0.05$).

Conclusions

Both Computer-aided indirect bonding transfer methods can be used with confidence as it is accurate and within the clinically accepted limits. Sectional computer aided indirect bonding method revealed better results in all dimensions as it had better control, better tray seating and more accurate transfer and can be used in cases with mild crowding. Both methods are technique sensitive. Although transfer errors were mainly in occlusogingival dimension towards gingival and in buccolingual towards buccal direction, still errors were within clinically acceptable limits. Computer-aided indirect bonding proved better time frame compared to conventional indirect bonding. Excessive pressure on IBT could affect brackets position accuracy.

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