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Evaluation of Segmented versus Full Arch Three Dimensionally Printed Transfer Tray for Orthodontic Indirect Bonding: (A randomized clinical trial)

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Abstract

Objective: This study is conducted to overcome the problems of conventional indirect bonding technique, through investigating accuracy of two novel three dimensionally digitally printed indirect bonding transfer trays (full arch & segmented) in terms of accuracy of transferring brackets, rate of immediate bond failure and chair side time.

Methods: Fourteen patients (7 in each group) with mild to moderate crowding, requiring orthodontic treatment with full set of permanent teeth including second molars, will be selected for this study. A total of 196 brackets will be used (98 Full Arch Tray and 98 Segment Arch Tray). The same bracket type and bonding material will used in both groups. The accuracy of bracket transfer will be measured by 3 Shape Ortho planner software (Bracket Placement Module), rate of bond failure by counting number of debonded brackets upon tray removal & chair side time by using digital watch.

Results: Linear attachment deviations were within the clinically acceptable range of deviation (+/- 0.5 mm) in all three planes for both techniques. Both techniques showed no differences in linear directional deviation in the mesio-distal plane, occluso-gingival and bucco-lingual.

Conclusion: Both techniques appeared to be comparable for the percentage of linear directional deviation. Segmented tray technique showed less bond failure rates compared to the full arch tray technique; however the percentage of tube failure was higher than bracket failure in full arch bonding techniques. The chairside time difference between the two indirect bonding techniques was statistically significant, with the full arch tray technique taking less chairside time than segmented tray technique.

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Background

Indirect bonding technique was first introduced in 1972 by Silverman, Cohen, Gianelly and Dietz. Their technique depends mainly on bracket positioning on dental cast and their transfer intraorally by means of transparent vacuum tray.[1]The popularity of indirect technique increased recently because of its advantages over the direct one which include: more precise bracket positioning, which eventually will decrease the need of finishing bends and length of orthodontic treatment. Moreover, it reduces chair side time and thus it is considered a more comfortable technique for the patient.[2]

The accuracy of indirect bonding technique depends greatly on transfer tray. Thus, different materials of transfer tray were introduced since 1999 including: hybrid systems made of resin and silicone, either for full arch or segmented trays. In an attempt to reduce bond failure, *segmentation* of the indirect bonding tray was a suggestion, and segmented tray was found to be more efficient in controlling isolation and tray placement when compared to full arch tray, and hence reduces bond failure.[3] Segmented tray was introduced either fabricated of two segments only (one for each quadrant) or three segments (one anterior and two posterior segments) for each arch.

Concerning *accuracy of bracket positioning* using indirect bonding technique, this may be attributed to any contamination that may occur during transfer, thickness of bonding material between teeth & brackets or any error that occurred during transfer tray fabrication. However, segmented trays showed high accuracy of bracket positioning during transfer reaching 98% regarding buccolingual & mesiodistal dimension.[4]

From the main disadvantages of indirect bonding technique is *bond failure.* It was found that the percentage of bond failure is 3.54% for direct technique, 5.79% for indirect one.[5]A modified technique was then introduced called modified Fantozzi technique which involves 2 trays of different materials, the inner one is soft while the outer one is rigid. This technique decreases rate of bond failure during removal of soft tray and at the same time more precise & stable bracket placement which is achieved by rigid tray.[6]

Several studies were conducted to reach a reproducible technique with standard results; however none have reached to the most reliable technique because of the human factor that can't be excluded starting from bracket placement and ending with bracket transfer using transfer tray.[7] *Digitization* was recently introduced in orthodontic field with the evolution of 3D imaging & printing machinery. These new technologies offer superb accuracy as well as elimination of errors emerging from human variations. Intraoral scanner devices offer numerous applications in orthodontics such as digital storage of study models and advanced software for bracket placement, enabling fabrication of three dimensionally printed bracket transfer tray.[8] Therefore, utilization of 3D imaging and printing techniques can help the orthodontist to reach the most precise and reproducible indirect bonding technique with more accurate and standard results.

Thus to overcome previously mentioned problems of conventional indirect bonding technique, this study is conducted in an attempt to investigate accuracy of two novel three dimensionally printed indirect bonding transfer tray (full arch & segmented) in terms of accuracy and immediate bond failure.

Material & Methods

This randomized controlled trial 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 after clinical and radiographic examination proved them eligible for a non-extraction based orthodontic treatment. Eligible patients were enrolled in a consecutive series. Non-syndromic, non-

extraction with 2-4 mm crowding cases were included. All patients will be treated by fixed orthodontic appliances using indirect bonding technique (Silverman, 1972).The key of modification is digital bracket placement using *bracket placement module of 3 Shape Ortho planner Software* (3Shape Company-Copenhagen, Denmark) instead of manual bracket placement directly on study model, and fabrication of segmented digital bracket transfer tray using *bracket transfer module* of same software instead of vacuum transfer tray. Regarding control group, all patients of this group will follow same steps of indirect bonding procedure as treatment group but the tray fabricated will be full arch tray instead of segmented one. Chairside time will be recorded & number of debonded brackets will be recorded following tray removal. Comparison between position of brackets on pre & post-operative scan will be done.

The following steps will be performed for each patient:

Initial records:

- *Case History:* Personal information, Medical & Dental History.
- *Study Model:* An impression of upper & lower arches will be taken using condensation silicone elastomeric impression material in a metal tray with patient fully awake and without any anesthesia in a clinical setting. The upper impression will be carefully scanned by desktop scanner.
- *Photographs:* Standardized digital photographs (frontal, profile, oblique) will be taken with a Canon EOS 750D digital camera (Canon, Tokyo, Japan) for all patients.
- *Panoramic Radiographs:* Standardized panoramic radiographs will be taken for all patients.
- *Lateral Cephalometric Radiograph:* Standardized lateral cephalometric radiographs will be taken for all patients.

1. **Scanning & digital bracket placement:** The upper arches will be carefully scanned (preoperative scan) by intraoral 3D scanner of 3Shape Company (Copenhagen, Denmark) & 3D model will be used for digital bracket placement.
2. **Fabrication of trays:** 3D printing of segmented digital bracket transfer tray (two segments; splitted at the midline) ,as shown in figure 2, for patients of treatment group & full arch tray will be fabricated for control group as shown in figure 1. Trays will be printed using Dent 1 3D Printer (Mogassam, Cairo, Egypt) with XY resolution 50 um & Z layer thickness 25 um and capability of printing up to 3 cm per hour. The printer also allows the use of any kind of printing resin

Fig. 1 Full arch tray

Fig. 2 Segmented tray

3. **Clinical application of digital tray:**

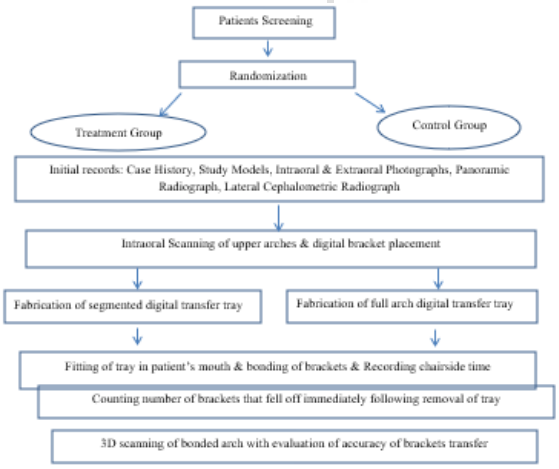
- Fitting of metal brackets into digital tray & ensure keeping them in place in their precise rooms created for them.
- Teeth to be bonded are polished and etched.
- Teeth isolation & moisture control are achieved.
- Adhesive bond is applied to teeth and composite is applied to brackets (3M Unitek, Monrovia, California, USA) fitted to digital trays.
- Placement of tray with brackets on prepared teeth carefully & ensure complete fitting of tray.
- Start curing of composite.

- Chair side time will be recorded.

Tray Removal

- After complete curing of composite, digital tray will be removed carefully.
- Number of brackets that will be debonded following tray removal will be counted & recorded.
- Scanning of bonded teeth (Post-operative scan) by intraoral 3D scanner of 3Shape company (Copenhagen, Denmark) & position of brackets will be compared with preoperative scan by superimposition of brackets scanned pre & post-operatively by the aid of colour map.

To sum up, participant timeline can be summarized as follows:



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 by the two different digital trays in terms of mesiodistal (Table 2), occlusogingival (Table 3), buccolingual (Table 4) deviations.
3. Bonding failure of orthodontic attachments between the two indirect bonding techniques (Table 5).
4. Chairside time between the two indirect bonding techniques (Table 6).
5. Inter-observer & Intra-observer Reliability (Table 7 & 8).

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

Table (1): Normality exploration of each attachment on each tooth for both groups:

N: Attachments count

		N	P - value	
			Group I (Segmented Tray)	Group II (Full Arch Tray)
Linear Measurements	**Mesio-distal Deviation (X-axis)**	144	>0.05	>0.05
	Occluso-gingival Deviation (Z-axis)	144	>0.05	>0.05
	Bucco-lingual Deviation (Y-axis)	144	>0.05	>0.05
Angular Measurements	Tip Difference	144	>0.05	>0.05
	Torque Difference	144	>0.05	>0.05
	Rotational Difference	144	>0.05	>0.05
Chair side time		144	>0.05	>0.05

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

	Mesial	Distal	P-value
Group I (Segmented Tray)	45 %	55%	**0.631**
Group II (Full Arch Tray)	40 %	60 %	**0.337**
P-value	**0.808**	**0.810**	

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

	Occlusal	Gingival	P-value
Group I (Segmented Tray)	47%	53 %	**0.337**
Group II (Full Arch Tray)	65 %	35%	**0.152**
P-value	**0.384**	**0.381**	

Table (4): Percentages of buccal and lingual deviations in group I and II:

	Buccal-out	Lingual- in	P-value
Group I (Segmented Tray)	42 %	58 %	**0.431**
Group II (Full Arch Tray)	47 %	53%	**0.775**
P-value	**0.809**	**0.849**	

**Significant difference*
%; Percentage, P: Probability level

Table (5): Total count of attachment failure of brackets and tubes for both groups:

	Group				P-value
	Group I (Segmented Tray)		Group II (Full Arch Tray)		
	Brackets (Number)	Tube (Number)	Brackets (Number)	Tubes (Number)	
Number of Failure	1	1	3	4	0.031*
Total Number of Attachments	60	12	60	12	
Percentage of Failure	1.6%	8.3%	5%	33.3%	

**Significant difference*
%; Percentage, P: Probability level

Table (6): Showing means and standard deviations in chairside time between segmented tray and full arch digital tray:

	N	Group				P-value
		Group I (Segmented Tray) (minutes)		Group II (Full Arch Tray) (minutes)		
		M	SD	M	SD	
Chair Side Time	**12**	**17.3**	**0.05**	**15.4**	**0.02**	**0.005***

N; Patients Count, M: Mean, SD: Standard Deviation, P: Probability level
**significant difference*

Table (7): Intra-observer reliability of linear measurements in both groups

	Intra-observer reliability		Group I	Group II
Linear measurements	Mesiodistal	1	0.96	0.98
		2	0.92	0.94
		3	0.93	0.96
		4	0.88	0.91
		5	0.95	0.96
		6	0.83	0.98
	Occlusogingival	1	0.95	0.96
		2	0.96	0.98
		3	0.94	0.96
		4	0.97	0.87
		5	0.95	0.93
		6	0.97	0.94
	Buccolingual	1	0.98	0.82
		2	0.93	0.94
		3	0.98	0.85
		4	0.98	0.841
		5	00.95	0.98
		6	0.99	0.97

- *≥ 0.5 (reliable=agreement).*

Table (8): Inter-observer reliability of linear measurements in both groups

	Intra-observer reliability		Group I	Group II
-Linear measurements	Mesiodistal	1	0.95	0.94
		2	0.99	0.98
		3	0.98	0.97
		4	0.92	0.90
		5	0.95	0.95
		6	0.92	0.94
	Occlusogingival	1	0.91	0.9
		2	0.92	0.9
		3	0..97	0.93
		4	0.95	0.94
		5	0.98	0.93
		6	0.98	0.97
	Buccolingual	1	0.97	0.78
		2	0.92	0.93
		3	0.98	0.95
		4	0.96	0.93
		5	0.96	0.96
		6	0.93	0.98

- *≥ 0.5 (reliable=agreement).*

DISCUSSION

Placement of orthodontic attachments on the patient's dentition is usually accomplished by either a direct or an indirect bonding technique. Indirect bonding was first developed by **Silverman and Cohen**[9] (1972) to reduce clinical time and to enhance patient comfort. The indirect bonding technique allows better three-dimensional visualization of tooth positioning and, as a result, greater accuracy while positioning orthodontic attachments will be achieved. Accurate bracket placement early in treatment will reduce the need for later repositioning or complex wire bending at the finishing stage, thus improving efficiency of treatment and shortening treatment time, which will reduce the complications accompanying orthodontic treatment such as white spot lesions and root resorption and will increase patient satisfaction.

Various modifications have been suggested to improve the indirect bonding technique, in order to yield better clinical results. With the evolution of 3D imaging techniques and 3D printing methods, 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 expected to be replaced by digital study models. Such evolution also used while measuring different outcomes that are used to evaluate any novel indirect transfer tray. As **Grunheid *et al*[10] *(2016)*** used CBCT to scan the models and polyvinyl siloxane as a transfer tray to be the only in vivo study carried out, while all other studies where in vitro. Thus unfortunately, no sufficient evidence compared the accuracy of different transfer tray and their designs.

Design of current study was chosen as randomized controlled trial because such design is at the top of hierarchy of evidence, providing highest level of evidence.

All the participants were encouraged to make full mouth scaling and polishing prior to bonding taking in order to ensure a healthy periodontium and provide a clean tooth surface ready for bonding. Moreover, any chipped incisal edges were smoothened in orderto allow for maximum precision and tray seating during bonding. However, teeth with enamel hypoplasia were excluded to avoid jeopardizing bonding ability.

Concerning the accuracy of attachment transfer in all three planes was measured using the method that is described by **Elnigoumi**[11] which was based on the reliability of 3D models in terms of linear and angular measurements. He carried out the study using digital scans and digital measurements on (Geomagic software version 12). The usage of digital scanning had the following advantages: (1) Precise and reproducible measurements unlike the 2D photography images that were used previously, (2) Capturing minute details up to parts of microns due to the ultimate accuracy of intraoral scanners and (3) Prevention of subjecting the patient to any kind of unnecessary radiation such as CBCT which was used earlier to test the accuracy of indirect bonding.

Referring to the results of the present study, it was essential to highlight the statistical findings of the different outcomes of the current study. Furthermore, it was mandatory to compare them to the findings of similar studies in the previous literature.

As for ***accuracy of attachment transfer***, linear measurements were done for each attachment. Any deviation in the attachment position (linear and/or angular), refers to the positioning of the attachment itself. For example, a value of 0.1 mm in a certain plane would reflect that the tube was bonded 0.1 mm away from the position it was originally intended based on the working model. For linear measurement deviation, the readings were compared relative to the accepted range of +/- 0.5 mm which was reported by **Grunheid et al**[10].

Regarding the ***chairside time*** between the two used indirect bonding techniques, there was a statistically significant difference, where the mean clinical chairside time of full arch tray was (15:4 minutes), while the segmented tray for the full arch was (17:3 minutes). This finding was similar to **Bozelli et al.**[12] (2013) who came up with the conclusion that the clinical time for bonding using segmented tray (6.3 minutes per segment, 12.6 minutes per arch) and full arch tray (14.8 minutes). Such difference in clinical time can be explained that latter study has not

included tubes during bonding. Regarding clinical time of full arch tray, the finding of present study was similar to **Yildirim and Adinatay**[13] who reported their chairside time in indirect bonding technique to be (15 minutes). Moreover, considering the indirect bonding techniques themselves, there was lack of sufficient evidence comparing the chairside time between indirect bonding techniques.

Referring to the survival of orthodontic attachments in the patient's mouth, there was lack of enough evidence comparing ***bond failure*** between segmented and full arch indirect transfer tray. When comparing the bond failure between the two indirect bonding techniques, the differences were statistically significant. The results of the current study for the segmented & full arch tray were (1.6% & 5%) respectively regarding brackets, and (8.3% & 33.3%) respectively regarding tubes. These data were in agreement with the finding of **S. Thiyagarajah el al**.[14] (2006) who concluded 2.2% bracket failure using segmented tray. The possible cause for the decrease of percentage of bond failure is the softness of digital tray material in comparison to the vacuum tray used in this study. Moreover, **Menini** et al.[15] (2014) conducted a study to measure bond failure using segmented transfer tray and the percentage of failure was 2.4%, which was not expected since the tray used was segmented into three segments (one anterior, two posterior segments) with higher failure rate in posterior segments.

The overall findings of this study revealed that the two indirect bonding techniques appeared to be accurate with the segmented tray showing significant reduction in bond failure rate and significant increase in chairside time.

Conclusions

From the results of the clinical and statistical analyses, and within the limitations of this trial, the following conclusions could be withdrawn. Linear attachment deviations were within the clinically acceptable range of deviation (+/- 0.5 mm) in all three planes for both techniques. Both techniques showed no differences in linear directional deviation in the mesio-distal plane, occluso-gingival and bucco-lingual. Segmented tray technique showed less bond failure rates compared to the full arch tray technique, however the percentage of tube failure was higher than bracket failure in full arch bonding techniques. The chairside time difference between the two indirect bonding techniques was statistically significant, with the full arch tray technique taking less chairside time than segmented tray technique.

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