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

Mariam El Sebaay (1), Khaled Hazem(2), Amr Ragab El-Beialy (3) and Mai Hamdi Aboul Fotouh (4)

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 be 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.

1. Master’s degree Student Orthodontic Department, Faculty of Dentistry, Cairo University
2. Professor of Orthodontics Orthodontic Department, Faculty of Dentistry, Cairo University
3. Associate Professor of Orthodontics Orthodontic Department, Faculty of Dentistry, Cairo University
4. Lecturer of Orthodontics, Faculty of Dentistry, Cairo University
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. 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.

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. 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.

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 3Shape 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.

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:

| Attachments count | N | P-value | Group I (Segmented Tray) | Group II (Full Arch Tray) |
|-------------------|---|---------|--------------------------|---------------------------|
| Linear Measurements | Mesiodistal Deviation (X-axis) | 144 | >0.05 | >0.05 |
| | Occlusogingival Deviation (Z-axis) | 144 | >0.05 | >0.05 |
| | Buccolingual 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 |
| Chairside 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                      | Number of Failure | Linear measurements |
|---------------------------|-------------------|---------------------|
| Group I (Segmented Tray)  | 1                 | Mesiodistal         |
|                           |                   | Occlusogingival     |
|                           |                   | Buccolingual        |
| Group II (Full-Arch Tray) | 1                 | Mesiodistal         |
|                           |                   | Occlusogingival     |
|                           |                   | Buccolingual        |

Total 80 12 80 12

Percentage of Failure: 1.64% 8.34% 8% 32.34%

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

| N  | Group                  | Chair Side Time (minutes) | P-value |
|----|------------------------|---------------------------|---------|
|    | Group I (Segmented Tray) | M    | SD  | Group II (Full Arch Tray) | M    | SD  |
| 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 |
|----------------------------|---------|----------|
| Mesiodistal                | 0.96    | 0.98     |
| Occlusogingival            | 0.96    | 0.96     |
| Buccolingual               | 0.96    | 0.96     |

≥ 0.5 (reliable = agreement)

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

| Intra-observer reliability | Group I | Group II |
|----------------------------|---------|----------|
| Mesiodistal                | 1       | 0.95     |
| Occlusogingival            | 2       | 0.99     |
| Buccolingual               | 3       | 0.98     |
|                            | 4       | 0.92     |
|                            | 5       | 0.95     |
|                            | 6       | 0.92     |

≥ 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 \textit{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.

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 \textit{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 \textit{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 Adinatat\textsuperscript{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 et al.\textsuperscript{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.\textsuperscript{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.

**References**

1) Klocke, A., Tadic, D., Chem, D., Vaziri, F., & Kahl-Nieke, B. Custom base preaging in indirect bonding. Angle Orthodontist. 2004; 74:106-111.
2) Guenthner TA, Larson BE. Indirect bonding: a technique for precision and efficiency. Semin Orthod. 2007; 13(1):58-63.
3) Sondhi A. Efficient and effective indirect bonding. Am J Orthod Dentofacial Orthop 1999; 115:352-9.
4) Gru, T., Lee, M. S. & Larson, B. E. Transfer accuracy of vinyl polysiloxane trays for indirect bonding. (1972). doi:10.2319/042415-279.1
5) Menini, A. et al. A 15-month evaluation of bond failures of orthodontic brackets bonded with direct versus indirect bonding technique : a clinical trial. 2014; 1–6 . doi:10.1186/s40510-014-0070-9
6) Cozzani M, Menini A, Bertelli A. Etching masks for precise indirect bonding. J Clin Orthod. 44:326-330
7) Nichols DA, Gardner G, Carballeyra AD, Marsh CM. Reproducibility of bracket positioning in the indirect bonding technique. Am J Orthod Dentofacial Orthop 2013; 144:770- 6.
8) Kravitz ND, Groth C, Jones PE, Graham JW, Redmond WR. Intraoral digital scanners.J Clin Orthod 2014; 48: 337-47.
9) Silverman E, Cohen M, Gianelly A, Dietz V. A universal direct bonding system for both metal and plastic brackets. Am J Orthod Dentofac Orthop. 1972; 62(3):236–44.
10) Grünheid T, Lee MS, Larson BE. Transfer accuracy of vinyl polysiloxane trays for indirect bonding. Angle Orthod. 2016;86(3):468-474. doi:10.2319/042415-279.1
11) El Nigoumi A. Assessing the Accuracy of Indirect Bonding with 3D Scanning Technology. 2016;37(06):613-619.
12) Grünheid T, Patel N, De Felippe NL, Wey A, Gaillard PR, Larson BE. Accuracy, reproducibility, and time efficiency of dental
measurements using different technologies. Am J Orthod Dentofac Orthop. 2014;145(2):157-164. doi:10.1016/j.ajodo.2013.10.012

13) Yıldırım K, Saglam-Aydinatay B. Comparative assessment of treatment efficacy and adverse effects during nonextraction orthodontic treatment of Class I malocclusion patients with direct and indirect bonding: A parallel randomized clinical trial. Am J Orthod Dentofac Orthop. 2018;154(1):26-34.e1. doi:10.1016/j.ajodo.2017.12.009

14) Schmid J, Brenner D, Recheis W, Hofer-Picout P, Brenner M, Crismani AG. Transfer accuracy of two indirect bonding techniques-an in vitro study with 3D scanned models. Eur J Orthod. 2018;40(5):549-555. doi:10.1093/ejo/cjy006

15) Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Diagnostic accuracy and measurement sensitivity of digital models for orthodontic purposes: A systematic review. Am J Orthod Dentofac Orthop. 2016;149(2):161-170. doi:10.1016/j.ajodo.2015.06
