



Accuracy of Orthodontic Indirect Bracket Bonding by CAD/CAM Transfer Tray

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Abstract

BACKGROUND: Indirect bonding is a technique in which orthodontic attachments are transferred from dental casts (working models) and bonded onto dentition using a transfer tray. Indirect bonding is a preferred technique for many orthodontists as it is less time consuming compared to direct bonding. Evolution in technology allowed forming transfer trays digitally by the integration of computer-aided design and computer-aided manufacturing (CAD/CAM).

AIM: This study was conducted to measure transfer accuracy of CAD/CAM indirect three-dimensional printed bonding trays.

MATERIALS AND METHODS: 140 teeth (all upper and lower incisors, canines, and premolars) in seven patients were bonded by vacuum-formed transfer tray formed on three-dimensional (3D) printed models with resin brackets. Intraoral scanner was used initially to obtain stereolithographic file for virtual brackets positioning and another scan was taken after brackets bonding. Superimposition of virtual STL files and post bonding STL files was done by Geomagic Qualify software to measure linear and angular deviation of brackets positions.

RESULTS: One sample t-test was performed to determine whether the mean transfer error was statistically within the selected acceptable limits of 0.5 mm for linear measurements. $p < 0.05$ indicated differences within the limits of 0.5 mm for linear measurements. All brackets were transferred within the accepted deviation limits.

CONCLUSIONS: CAD/CAM designed and printed transfer trays had high transfer accuracy in linear measurements in all teeth.

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Introduction

Since about 40 years ago, first straight wire appliance was introduced. An appliance composed of attachments (brackets) designed with specific characteristics for each tooth with pre-set tip, in and out and torque prescription [1].

Direct brackets bonding on their position used to be a time consuming process. To achieve desired movements of the teeth, an orthodontist will place the bracket in a particular place and orientation which may vary according to each case. The more accurate the brackets placement, the more likely that the desired teeth positioning will occur, so many orthodontists are preferring indirect bonding. Indirect bonding, described by Silverman *et al.* at 1972, is a technique in which orthodontic attachments are transferred from dental casts (working models) and bonded onto dentition using a transfer tray [2].

Regular indirect bonding protocol includes brackets bonding to plaster (physical) models and then transferred back to a patient's mouth using an indirect bonding transfer tray formed of silicon or vacuum formed sheets [3], [4], [5], [6].

At present, software evolution allows digital planning and placement of the brackets. This procedure includes a digital scan of the patient's models by desktop scanner, or digital scan of the patient's mouth by intra oral scanner. Once the brackets are placed on the digital models, a transfer tray holding brackets in their intended position is formed or printed then placed in the patient's mouth for bonding procedure. Christensen was the first to use a computer-aided design/computer aided manufacturing (CAD/CAM) produced indirect bonding transfer tray in 2018 [7], [8].

This study was designed to test null hypothesis that CAD/CAM transfer trays for indirect brackets bonding by 3D designing and printing technologies are accurate for brackets positioning transfer.

Materials and Methods

All subjects were informed about the nature, and benefits of the study and a written informed consent was obtained before the start of treatment. Ethical

approval was obtained from the ethical committee of the Faculty of Dentistry before enrolling the subjects consenting to participation.

Sample size was calculated based on evidence from Schmid *et al.* [9] and by considering the means and standard deviations of transfer errors. Assuming 80% power, 0.05 level of significance, mean and SD of transfer errors were 0.071 ± 0.052 . The minimum required sample size to detect statistical significance difference will be 90 brackets.

Seven patients indicated for fixed orthodontic treatment were selected from the outpatient clinic of the orthodontic department with fair oral hygiene. Patients with hypocalcified teeth or massive restorations extended to facial surfaces of teeth, insufficient oral hygiene, active periodontal disease, and multiple missing teeth were excluded from the study.

140 teeth (all upper and lower incisors, canines, and premolars in all patients) were included for indirect bonding in this study.

After full orthodontic records were taken, all participants were subjected to scaling and polishing. Intraoral scanner CS 3700 (Carestream dental, Georgia, USA) was used to obtain Standard Tessellation Language (STL) files for both dental arches.

STL file was transferred to ortho analyzer software (3Shape. Copenhagen, Denmark) and virtual models were obtained. Virtual placement of brackets was done and another STL file for the final brackets position design was obtained and used as reference for later superimposition.

Resin models with resin brackets were 3D printed from hard resin Model 2.0 resin (Nextdent, Netherlands) in segments (Figure 1). Then 1 mm soft sheet was thermoformed on the printed model to produce a vacuum formed transfer tray with negative replica of brackets places and brackets were fitted in the vacuum formed transfer trays (Figure 2).



Figure 1: 3D printed model with resin brackets

Indirect bonding procedure

All teeth were polished with brush and pumice then etched with 37% phosphoric acid for 20 s. Proper drying by air with paying attention to lingual and palatal surfaces of teeth, and isolation were done. Ortho solo



Figure 2: Vacuum formed transfer tray

bonding agent (Ormco, California, USA) was added to cover the etched surfaces with bonding brush. Greengloo light cured adhesive (Ormco, California, USA) was added over mesh of brackets bases inside transfer trays. Transfer trays loaded with brackets were put on teeth by gentle pressure followed by 20 s light curing for each bracket. Removal of the tray by dental probe started from lingual surface toward labial or buccal surfaces.

After complete bonding, teeth with bonded brackets were scanned by the same intra oral scanner and STL files for post-bonding models were saved for superimposition.

Superimposition

Superimposition was done by Geomagic Qualify software version 12.0 according to technique described by El-nigoumi in 2016 [10].

An ideal virtual attachment for the Morelli max 22 Roth prescription (Morelli, Brazil) bracket system was picked from 3 shape library and superimposed on scanned brackets using 4 squares representing 4 wings of the bracket.

Mesio-distal and occluso-gingival linear deviations were measured as the linear distance between the pre-center and post-center.

Statistical analysis

The mean and standard deviation values were calculated. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests, data of accuracy showed parametric (normal) distribution.

The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

One-tailed t-tests were performed to determine whether the mean transfer error was statistically within the selected acceptable limits of 0.5 mm for linear measurements. $p < 0.05$ indicated differences within the limits of 0.5 mm for linear measurements [11].

Results

16 brackets were debonded during transfer tray removal. All one sample t-tests reached statistical significance ($p < 0.05$) for all linear dimensions in all tooth types in both arches, indicating that the brackets were transferred with acceptable translational error in the MD and OG dimensions, regardless of tooth type or arch (Tables 1 and 2, Figure 3).

Table 1: The mean, standard deviation (SD) values of upper arch brackets

Variables	Accuracy		p-value
	Upper arch		
	Mean	SD	
Premolars			
MD (mm)	0.20	0.04	<0.001*
OG (mm)	0.23	0.05	<0.001*
Canines			
MD (mm)	0.20	0.04	<0.001*
OG (mm)	0.24	0.07	<0.001*
Incisors			
MD (mm)	0.22	0.03	<0.001*
OG (mm)	0.22	0.04	<0.001*
Total			
MD (mm)	0.21	0.04	<0.001*
OG (mm)	0.23	0.05	<0.001*

*Brackets position is within the pre-selected limits of 0.5 mm for linear measurements.

Table 2: The mean, standard deviation (SD) values of the lower arch brackets

Variables	Accuracy		p-value
	Lower arch		
	Mean	SD	
Premolars			
MD (mm)	0.21	0.04	<0.001*
OG (mm)	0.25	0.06	<0.001*
Canines			
MD (mm)	0.22	0.03	<0.001*
OG (mm)	0.24	0.05	<0.001*
Incisors			
MD (mm)	0.21	0.03	<0.001*
OG (mm)	0.25	0.05	<0.001*
Total			
MD (mm)	0.21	0.03	<0.001*
OG (mm)	0.25	0.05	<0.001*

*Brackets position is within the pre-selected limits of 0.5 mm for linear measurements.

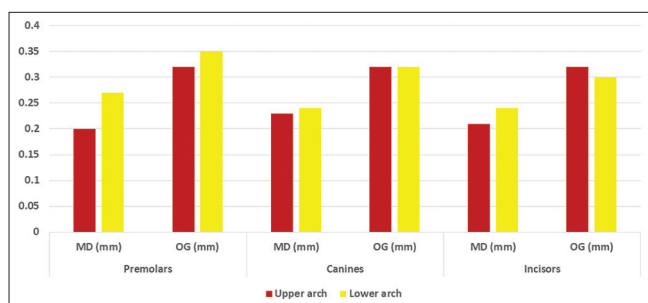


Figure 3: Bar charts representing relation between different arches

Discussion

This study was conducted to measure transfer accuracy of CAD/CAM indirect three dimensional printed bonding trays. Total of 140 brackets were bonded in this study. 16 brackets were debonded during transfer tray removal, which represent 11.4% of total bonded brackets. This percentage is slightly lower than

that found by Zachrisson and Brobakken who reported 14% bonding failure rate with indirect bonding [12].

One hundred twenty four brackets were measured for transfer accuracy. One sided tests showed that brackets were transferred within the acceptable range of 0.5 mm in linear measurements (occluso-gingival and mesio-distal).

This threshold value of 0.5 mm was used because they represent widely accepted professional limits. The American Board of Orthodontics Cast-Radiograph Evaluation cuts points for teeth with 0.5 mm or more deviation from proper alignment. This threshold has been utilized in several researches to assess tooth and bracket transfer accuracy in models superimposition [13], [14], [15].

According to Armstrong *et al.*, 0.25 mm transfer deviation in the incisor brackets positions and 0.5 mm for canines, premolars, and molars is considered clinically accepted [16].

The results showed that linear control of the brackets were within the accepted range. Similar results have been shown in the previous researches studying digital indirect bonding techniques [15], [17].

The previous studies have evaluated the accuracy and precision of the digital indirect bonding by comparing the actual brackets positions with the virtual setup through superimposition or direct measuring and they concluded that CAD/CAM indirect bonding is an accurate and efficient technique for orthodontic brackets bonding which agrees with this study results [13], [18], [19], [20].

Indirect bonding common errors that affect transfer trays construction including used material type, lack of elasticity, distortion (resulting in incorrect transfer of the bracket position), incorrect tray fit or pressure. Appropriate pressure would ensure proper seating of the tray while excessive pressure could cause gingival deviation or rotation of brackets [21].

Every effort was made to eliminate or reduce possible causes of inaccurate brackets transfer. 3D printer with high speed and high precision was used for printing models. Some transfer errors are attributed to intraoral scanning procedure [22]; therefore, intraoral scans were followed by desktop scans for study Models and superimposed to test scan accuracy. Carestream CS 3700 (Carestream dental, Georgia, USA) intra-oral scanner was used. It is characterized by high resolution and antireflection option, so it can be used to scan metal objects as brackets on post bonding scan without need for antireflection powder with minimum amount of distortion.

With technology evolution and further researches, standardization of printing settings and resin specification will be set and range of errors through the whole procedure will be reduced to minimum and CAD/CAM indirect bonding will be more popular in every orthodontist daily practice.

Conclusions

CAD/CAM indirect bonding transfer trays had high transfer accuracy in linear measurements in all types of teeth

References

- McLaughlin RP, Bennett JC. Evolution of treatment mechanics and contemporary appliance design in orthodontics: A 40-year perspective. *Am J Orthod Dentofacial Orthop.* 2015;147(6):654-62. <https://doi.org/10.1016/j.ajodo.2015.03.012>
PMid:26038069
- Silverman E, Cohen M, Gianelly AA, Dietz VS. A universal direct bonding system for both metal and plastic brackets. *Am J Orthod.* 1972;62(3):236-44. [https://doi.org/10.1016/s0002-9416\(72\)90264-3](https://doi.org/10.1016/s0002-9416(72)90264-3)
PMid:4559001
- Aguirre MJ, King GJ, Waldron JM. Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. *Am J Orthod.* 1982;82(4):269-76. [https://doi.org/10.1016/0002-9416\(82\)90461-4](https://doi.org/10.1016/0002-9416(82)90461-4)
PMid:6760721
- Koo BC, Chung CH, Vanarsdall RL. Comparison of the accuracy of bracket placement between direct and indirect bonding techniques. *Am J Orthod Dentofacial Orthop.* 1999;116(3):346-51. [https://doi.org/10.1016/s0889-5406\(99\)70248-9](https://doi.org/10.1016/s0889-5406(99)70248-9)
PMid:10474109
- Hodge TM, Dhopatkar AA, Rock WP, Spary DJ. A randomized clinical trial comparing the accuracy of direct versus indirect bracket placement. *J Orthod.* 2004;31(2):132-7. <https://doi.org/10.1179/146531204225020427>
PMid:15210929
- Bozelli JV, Bigliuzzi R, Barbosa HA, Ortolani CL, Bertoz FA, Faltin Junior K. Comparative study on direct and indirect bracket bonding techniques regarding time length and bracket detachment. *Dental Press J Orthod.* 2013;18(6):51-7. <https://doi.org/10.1590/s2176-94512013000600009>
PMid:24351150
- Christensen LR, Cope JB. Digital technology for indirect bonding. *Semin Orthod.* 2018;24(4):451-60. <https://doi.org/10.1053/j.sodo.2018.10.009>
- Layman B. Digital bracket placement for indirect bonding. *J Clin Orthod.* 2019;53(7):387-96.
PMid:31648214
- 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):549-55. <https://doi.org/10.1093/ejo/cjy006>
PMid:29471483
- El Nigoumi A. Assessing the accuracy of indirect bonding with 3D scanning technology. *J Clin Orthod.* 2016;50(10):613-9.
PMid:27888654
- Casko JS, Vaden JL, Kokich VG, Damone J, James RD, Cangialosi TJ, et al. Objective grading system for dental casts and panoramic radiographs. American board of orthodontics. *Am J Orthod Dentofacial Orthop.* 1998;114(5):589-99. [https://doi.org/10.1016/s0889-5406\(98\)70179-9](https://doi.org/10.1016/s0889-5406(98)70179-9)
PMid:9810056
- Zachrisson BU, Brobakken BO. Clinical comparison of direct versus indirect bonding with different bracket types and adhesives. *Am J Orthod.* 1978;74(1):62-78. [https://doi.org/10.1016/0002-9416\(78\)90046-5](https://doi.org/10.1016/0002-9416(78)90046-5)
PMid:356618
- Larson BE, Vaubel CJ, Grünheid T. Effectiveness of computer-assisted orthodontic treatment technology to achieve predicted outcomes. *Angle Orthod.* 2013;83(4):557-62. <https://doi.org/10.2319/080612-635.1>
PMid:23181776
- Grünheid T, Lee MS, Larson BE. Transfer accuracy of vinyl polysiloxane trays for indirect bonding. *Angle Orthod.* 2016;86(3):468-74. <https://doi.org/10.2319/042415-279.1>
PMid:26355994
- Niu Y, Zeng Y, Zhang Z, Xu W, Xiao L. Comparison of the transfer accuracy of two digital indirect bonding trays for labial bracket bonding. *Angle Orthod.* 2021;91(1):67-73. <https://doi.org/10.2319/013120-70.1>
PMid:33289807
- Armstrong D, Shen G, Petocz P, Darendeliler MA. A comparison of accuracy in bracket positioning between two techniques-localizing the centre of the clinical crown and measuring the distance from the incisal edge. *Eur J Orthod.* 2007;29(5):430-6. <https://doi.org/10.1093/ejo/cjm037>
PMid:17660488
- Bachour PC, Klabunde R, Grünheid T. Transfer accuracy of 3D-printed trays for indirect bonding of orthodontic brackets. *Angle Orthod.* 2022;92(3):372-9. <https://doi.org/10.2319/073021-596.1>
PMid:35006236
- Son KH, Park JW, Lee DK, Kim KD, Baek SH. New virtual orthodontic treatment system for indirect bonding using the stereolithographic technique. *Korean J Orthod.* 2011;41(2):138-46.
- Brown MW, Koroluk L, Ko CC, Zhang K, Chen M, Nguyen T. Effectiveness and efficiency of a CAD/CAM orthodontic bracket system. *Am J Orthod Dentofacial Orthop.* 2015;148(6):1067-74. <https://doi.org/10.1016/j.ajodo.2015.07.029>
PMid:26672713
- El-Timamy AM, El-Sharaby FA, Eid FH, Mostafa YA. Three-dimensional imaging for indirect-direct bonding. *Am J Orthod Dentofacial Orthop.* 2016;149(6):928-31. <https://doi.org/10.1016/j.ajodo.2015.12.009>
PMid:27242004
- Aksakalli S, Demir A. Indirect bonding: A literature review. *Eur J Gen Dent.* 2012;1(01):6-9.
- Abduo J, Elseyoufi M. Accuracy of intraoral scanners: A systematic review of influencing factors. *Eur J Prosthodont Restor Dent.* 2018;26(3):101-21. https://doi.org/10.1922/EJPRD_01752Abduo21
PMid:29989757