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Accuracy Of Computer-Aided vs Conventional Indirect Bonding of Orthodontic Brackets

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Abstract:

Objective: to evaluate the accuracy of computer-aided conventional indirect bonding of orthodontic brackets.

Design: Two arms randomized controlled clinical trial with an allocation ratio of 1:1.

Setting: The outpatient department of the dental college, Ain Shams University.

Participants: 20 adult patients seeking orthodontic treatment.

Methods: All patients had the indirect bonding. The experimental group consisted of 10 patients who received computer-aided indirect bonding. All participants were optically scanned after indirect bonding procedure to evaluate the accuracy of bracket transfer

Results: There is a statistically significant difference between the two groups in the mesiodistal ($p<0.001$) occlusogingival dimension ($p=0.005$) and in the torque and rotation dimensions (both at $p<0.001$). Specifically, the magnitude of the discrepancy is greater in the computer group all measurements, but all discrepancy values fall below the clinically accepted threshold.

Conclusion: conventional indirect bonding method proved high level of accuracy and simplicity and computer-aided indirect is very accurate, reliable, within the accepted clinical errors limit**.**

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Introduction:

In recent years, indirect bonding popularity increased due to its advantages as reduction of chair time and enhancement of patient comfort. Although the techniques of indirect bonding has improved over the years, the literature has shown different techniques of bracket placement; furthermore, different materials were specially developed for this technique.

The theoretically more ideal bracket placement which is intended to be achieved in indirect bonding is of no importance to the orthodontist unless the bracket position planned in the set-up is transferred with complete accuracy to the patient's dentition. Recent methods of evaluating the accuracy of bracket position were used in this study, which opened the door for precise evaluation for all of the indirect bonding techniques available in the market either computer-aided or manual techniques.

As for conventional indirect bonding, White[1] for example used Tacky Glue to precisely place brackets on the cast which was simple, inexpensive, water-soluble adhesive. The glue was removed during the tray transfer stage. He also used a hot-glue gun to form the matrix of the transfer tray construction.

There are multiple indirect bonding techniques for lingual orthodontics as well. Orapix®[2] (Orapix, Seoul, Korea) system showed improved results. Another system, Incognito® (TOP Service, Bad Essen, Germany) System provides better results and reduces bond failure rate.Many studies have been performed to evaluate accuracy and reliability in indirect bonding techniques, most of these studies assess either the bracket placement accuracy or the bond and shear strength compared to direct bonding or the precision of the used transfer tray.

Linn et al [3] for example compared the SBS values of the indirect and direct bonding groups in 2006. Sixty teeth were divided into three groups; one group used light-cured resin (Transbond XT) for direct bonding; another group used chemically-cured resin (Sondhi Rapid Set) for indirect bonding; and the last group used light-cured resin (Enlight LV) for indirect bonding. No differences were found among the groups.

In 2015, *Michael S. Lee et al* [4] used cone beam computed tomography (CBCT) to capture 3-D data for the first time in order to assess the accuracy of vinyl polysiloxane trays for indirect bonding and it was found to have high positional accuracy.

Also in 2015, *Kelley A. Gyllenhaal* [5] submitted a research aiming to compare the accuracy of the transfer tray of two indirect bonding methods. A software was used for comparing models, aiming to superimpose models based on a surface best-fit algorithm. Differences bracket position were analyzed in three translational planes linearly and three rotational planes of space to the nearest 1 μm. The pre- and post-transfer bracket position differences were statistically analyzed to detect, to compare any directional patterns of error, and to compare the transparent and opaque tray systems. Finally they concluded that both indirect bonding methods guarantee proper bracket position transferring in actual clinical use.

In 2018 *Schmid et al* [6] evaluated the transfer tray accuracy between two different indirect bonding techniques (Silicone and double vaccum trays) using 3d scanned models using 3shape scanner and GOM inspect software for superimposition and found that, with both indirect bonding methods, 100 per cent of the transversal and horizontal measurements of both methods were within the clinically acceptable range of 0.25 mm, with silicon trays, 95.9 per cent of the angular and 98.5 per cent of the vertical measurements were within the range of 1° and 0.25 mm, respectively, with vaccum trays method, 84.8 per cent of the angular and 94 per cent of the vertical measurements were also within the clinically acceptable range, although both transfer methods showed a high precision, they concluded that silicone trays scored better in terms of accuracy than double-vacuum forms.

Materials and Methods:

A total of 20 patients were recruited from the outpatient clinic of the Orthodontic Department at the Faculty of Dentistry Ain Shams University, they were allocated randomly 1:1 ratio into 2 groups, conventional group and computer-aided group. Inclusion criteria: All participants were planned to receive indirect bonding during the treatment planning phase for either maxilla, mandible or both, patients with ages ranging from from12 to 30 years, all permanent teeth present excluding the third molars, and normal or increased overjet, while Exclusion criteria was: medical problems that affect tooth movement (e.g. osteoporosis, bisphosphonate therapy, etc...), any dental pathology that may affect the enamel surface e.g.: Enamel defect, severe crowding preventing proper bracket placement on the labial/buccal tooth surface, bad oral hygiene (will be evaluated through plaque index & pocket depth), and if participants had extractions before bonding or actively erupting teeth.

Methods: An informed consent was signed by each patient before their enrollment in the current study in which the aim of the study, the methodology and possible complications will be clearly described. Full orthodontic records were taken for the patients who met the inclusion criteria. These records are: Extra-oral and intra-oral photographs, orthodontic study casts, panoramic and cephalometric radiographs.

After obtaining participants' casts, they were scanned in the computer-aided group using 3Shape R-750 intra oral scanner*, then virtual bracket placement was performed using 3Shape Orthoalayzer software, followed by indirect bonding tray designing by 3Shape appliance designer software, the exported .stl file for the indirect bonding tray was then 3d printed and brackets were delivered in it, in the conventional bonding group, brackets were positioned on the cast and indirect bonding tray was designed according to White[1] indirect bonding methodology.

Participants were optically scanned using 3Shape TRIOS intraoral scanner after indirect bonding, GOM inspect software was used to evaluate the difference between pre- and post-transfer records using local coordinate system.

Error of measurement: The error of measurement in this study was assessed through assessing the intra-operator and inter-operator reliability.

Statistical Analysis: Numerical data were explored for normality by checking the data distribution and using Shapiro-Wilk tests. All data showed normal (parametric) distribution. Student's t-test was used to compare between the two groups. The significance level was set at $P \leq 0.05$. Statistical analysis was performed using SPSS 23 (IBM SPSS).

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Results: ***Figure (1) illustrates the subject flow through the trial using a CONSORT diagram.***

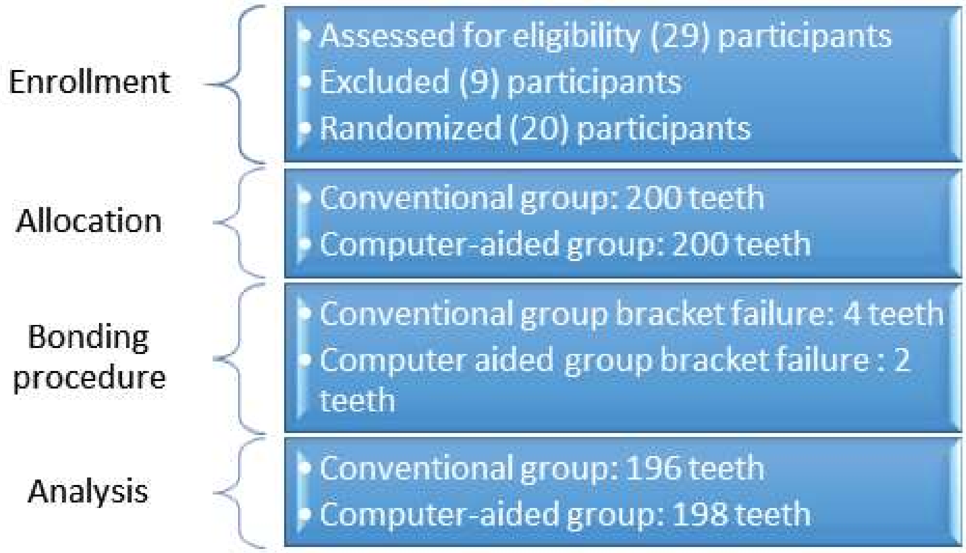

Figure 1 CONSORT Flow Chart

Paired t-test was used to compare the mean and standard deviation (SD) values for both groups

Table 1 T-test for Computer vs. conventional groups

absolute	Computer		Conventional		Paired Differences				p-value
			Mean Mean	SD SD	95% Confidence Interval of the Difference				
	Mean	SD					Lower	Upper	
Buccolingual BL (linear)	0.27	0.22	0.25	0.25	0.02	0.32	-0.02	0.07	0.298 NS
Mesiodistal MD (linear)	0.16	0.14	0.07	0.09	0.09	0.16	0.07	0.11	<0.001*
Occlusogingival OG (linear)	0.27	0.21	0.18	0.16	0.07	0.35	0.02	0.12	0.005*
Rotation (Angular)	1.54	1.25	1.08	1.07	0.47	1.66	0.24	0.70	<0.001*
Tip (Angular)	1.78	1.27	1.58	1.32	0.17	1.81	-0.08	0.43	0.177 NS
Torque (Angular)	1.60	1.20	1.15	0.96	0.47	1.61	0.24	0.70	<0.001*

There is a statistically significant difference between the two groups in the Mesiodistal ($p<0.001$) occlusogingival dimension ($p=0.005$) and in the torque and rotation dimensions (both at $p<0.001$). Specifically, the magnitude of the discrepancy is greater in the computer group all measurements, but all discrepancy values fall below the clinically accepted threshold.

Directional patterns of error:

Histogram plots were generated to illustrate the direction of the errors detected for each of the six dimensions.

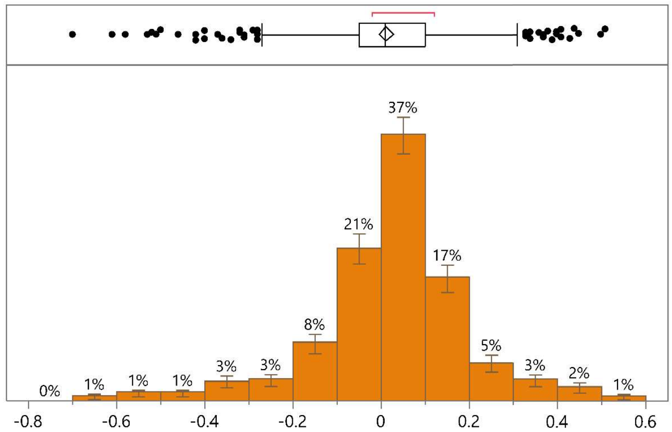

Figure 2 Histogram plot for mesiodistal discrepancy. Negative values represent a mesial translation and positive values represent a distal translation. From this plot it seems the data is not significantly skewed in either direction.

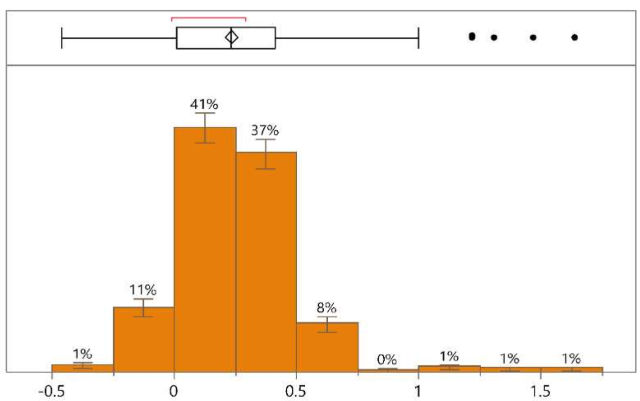

Figure 2 : Histogram plot for buccolingual discrepancy. Negative values represent a lingual translation and positive values represent a buccal translation. From this plot it seems the data is skewed towards the buccal.

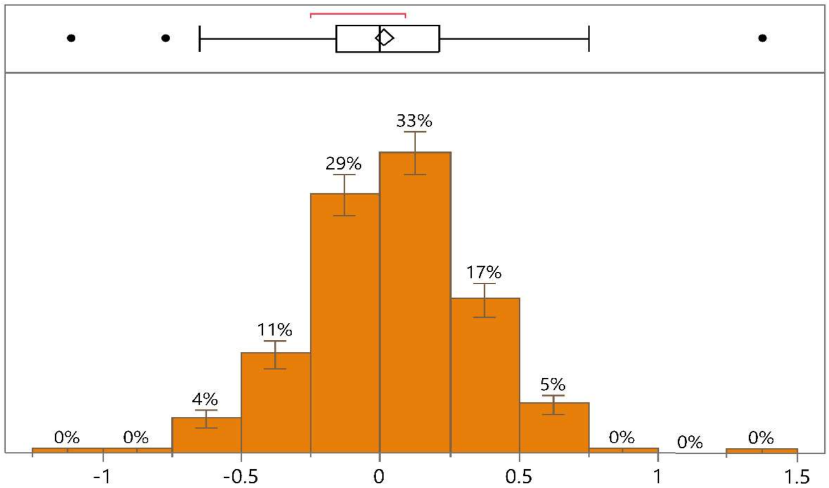

Figure 3 Histogram plot for occlusogingival discrepancy. Negative values represent an occlusal translation and positive values represent a gingival translation. From this plot it seems the data is not significantly skewed in either direction.

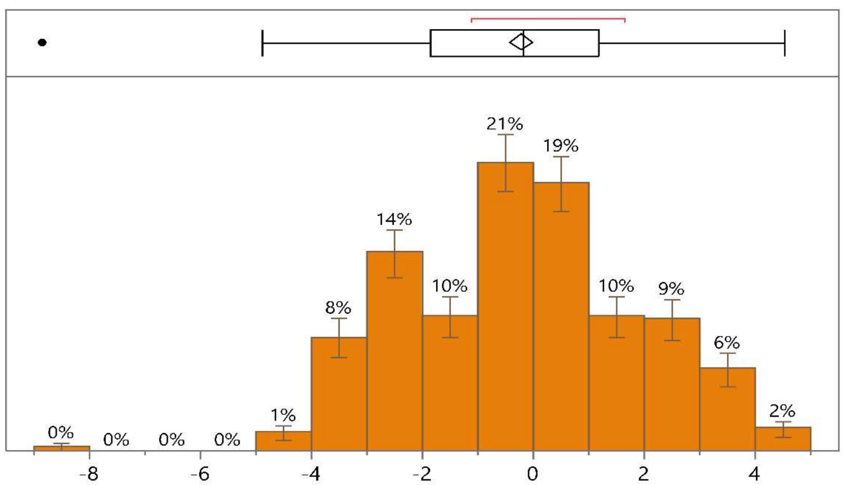

Figure 4 Histogram plot for tip discrepancy. Negative values represent a mesial tip and positive values represent a distal tip. From this plot it seems the data is not significantly skewed in either direction.

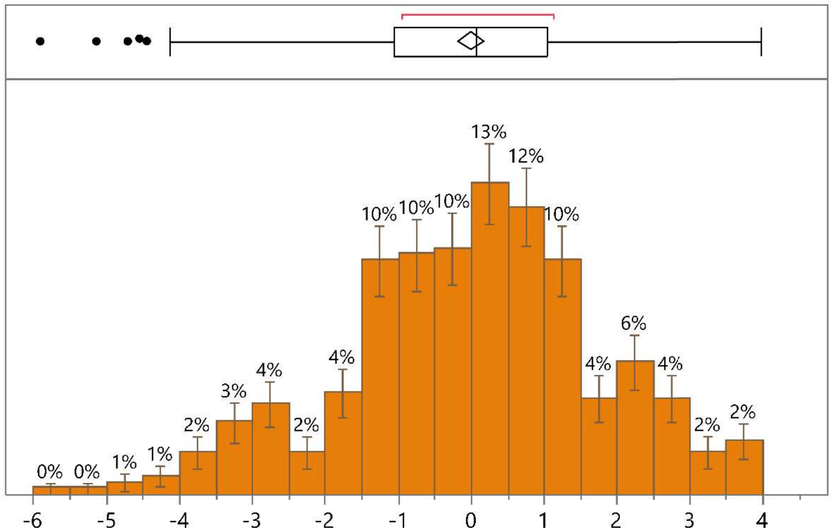

Figure 6 Histogram plot for torque discrepancy. Negative values represent a labial crown torque and positive values represent a lingual crown torque. From this plot it seems the data is not significantly skewed in either direction.

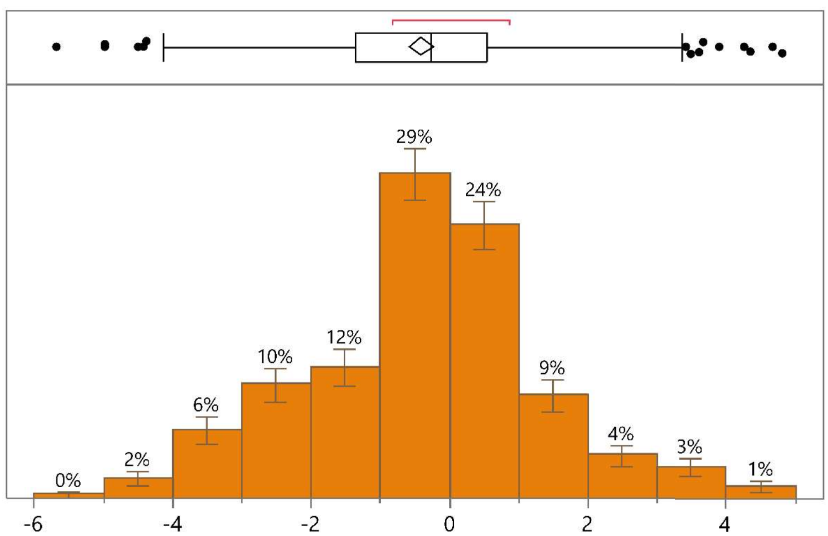

Figure 7 Histogram plot for rotation discrepancy. Negative values represent mesial rotation and positive values represent a distal rotation. From this plot it seems the data is not significantly skewed in either direction.

Discussion:

In study design, 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 time of impression and bonding time. Upper and lower arches were included to assess accuracy in different teeth anatomy.

Severely crowded as well as decreased ovejet cases were excluded from this study as proper tray seating, and eventually the accuracy of transfer tray evaluation may not have been achieved properly. Virtual study models of all of our sample was obtained using 3shape R-750 desktop scanner was used in this study due to its easy use, reduced cast scanning time, and the availability in our Ainshams University .As for computer-aided indirect bonding group, our choice was to use 3shape software*, as it has several modules with an easy, attractive interface that allowed us for proper scanning, bracket placement using heights recommended by White [1], and transfer tray designing. Ortho analyzer software from 3shape was used in bracket positioning for many reasons, in my opinion the most unique feature in this software is its brackets library which contains many types of orthodontic brackets which are available in our market and provide efficient treatment. Also simplified workflow starting from teeth segmentation till 100% precise bracket positioning was remarkable. Our choice was to use 0.22 inch pre-adjusted edgewise Discovery brackets** as it can be used in many treatment plans for our patients, also these brackets bases are optimally adapted to the contour of the tooth using CAD (Computer Aided Design) and ensure optimal handling. The anatomical contour simplifies positioning and bonding of the bracket to the tooth. When previously tested, a single layer IBT printed using the recommended resin material from the manufacturer, cracks and tray tearing were remarkably observed during seating. As Appliance designer software from 3shape was used in IBT designing and exporting as a .stl file, we were able to design our unique double layer IBT design, which gave us the required rigidity combined with adequate tooth visibility during bonding procedure, solving this problem to an acceptable limit. Trios intraoral scanner from 3shape was used in this study for its proven accuracy as many independent studies[7–9]and plaster models were made from the impressions. Each subject underwent full-arch intraoral scanning twice with a TRIOS scanner (3Shape, Copenhagen, Denmark reported statistically higher accuracy for TRIOS compared with conventional impressions and/or impressions made with other major intraoral scanners for full arch. Real life colors create digital impressions with exceptional quality in realistic colors which allows ease of communication with patients. Also provides Artificial Intelligence (AI) technology, it removes excess soft tissue from the digital impression allowing scanning to be easier. In this study we used White's [1] method for conventional transfer tray manufacturing as it's simple, convenient, and we are well trained to use it all the time in our University. It should be mentioned here that the same double layer IBT was used but using glue gun this time. In both groups, extension of IBT didn't cover the brackets gingival wing for easier excess composite removal. Three dimensional inspection and both angular/ linear measurements were obtained by GOM Inspect 2019 software that presents data with an accuracy and precision of up to 1 μm. It also creates 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 angularly and linear transfer accuracy of two indirect bracket bonding methods. To our knowledge, our study was the 1st study using GOM inspect software in determining brackets accuracy using local coordinate systems.

One of the theories held prior to performing this study was that posterior brackets would have higher incidence of failure, a potential explanation for this finding is that it is more difficult to hold indirect transfer trays as steadily and precisely in the posterior region than in other areas of the mouth because of limited accessibility. Our study found a bonding appointment bracket failure rate of 1.5% at placement for both transfer methods. Given proper isolation and first hand assistance, practitioners can feel confident that when they use an indirect bonding system in their office it will be both accurate and efficient.

Although our results showed that conventional indirect bonding was more precise, this could be due to that we are more experienced in this method, also different materials that are subjected to finger pressure during tray seating could be a possible explanation.

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** Discovery,Dentaurum

Histograms also showed that most of the discrepancies either +ve or –ve ones are very close to zero, so discrepancy in very insignificant. Only one histogram showed that the brackets have more tendency moving towards buccal, that makes sense due to excess composite that was remarkable.

To the best of our knowledge, our study is one of the first in-vivo studies that include more than one indirect bonding system for analysis and among the first to evaluate a computer-aided method in all the directions in space. Currently the present study has several strengths and some weaknesses. Compared to previous literature on indirect bonding, our study has a major advantage in that it is one of the first to perform the indirect bonding procedure in vivo on real patients. From start to finish, all clinical procedures exactly represented indirect bonding in an orthodontic office. Most of previous studies had used stone models or manikins, and thus did not factor in important clinical complications such as patient anatomy and behavior, moisture contamination, etc. It is understandably more difficult to achieve an accurate transfer when working in an actual patient's mouth. Therefore, we can say with confidence that our results are clinically salient. Secondly, our study is one of the first studies to use digital three-dimensional technology to perform analysis of bracket position. Former studies had used photographs for measurement or measured directly on models. One of the biggest advantages in using digital technology is the possibility to measure positional changes on a much smaller scale than is possible with traditional measurement tools. This allowed us to detect minor deviations that would likely not be recognized with other methods of measurement. Furthermore, with the use of 3D digital models it is possible to quantify changes in all directions of space. Using traditional measurement tools it is simple to measure linear discrepancies (mesiodistal,buccolingual, and occlusogingival) but it is much harder to recognize angular discrepancies such as tip, torque, and rotation.

Conclusion:

Conventional indirect bonding method proved high level of accuracy and simplicity, computer-aided indirect is very accurate, reliable, within the accepted clinical errors limits, indirect bonding methods that we used doesn't increase brackets bonding failures and could be used with confidence by the practitioners, excessive pressure on IBT could affect the accuracy of brackets position.

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