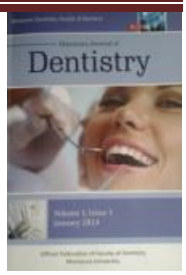

Bond failure rate of computer aided versus traditional bracket placement for indirect bonding technique: In vivo study

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Abstract:
Objective: To compare bond failure rates between traditional (Method I) and computer aided (Method II) indirect techniques for bonding orthodontic brackets.
Design: prospective randomized controlled clinical trial with split mouth design.
Materials and methods: fifteen subjects meeting the inclusion criteria were selected from orthodontic waiting lists and assigned to either of two study groups according to a split-mouth study design. The number of bracket failures with each group was recorded during the procedure, after first wire insertion and over a period of three months.
Results: seventeen brackets were lost from the 300 bonded teeth, giving an overall bond failure rate of (5.7%). There were 9 initial failures; 4 brackets of method I (2.7%) and 5 brackets of method II (3.3%). At 3-months follow up, 8 additional failures occurred; 6/146 in method I (4.1%) and 2/145 in method II (1.4%). There were no statistically significant differences in either the initial or the overall bond failure rates between the two methods.
Conclusions: There was no significant difference in the overall bond failure rates between digital (computer aided) and manual (traditional) indirect bonding techniques.

Introduction

Precise bracket placement, from the start, of orthodontic treatment is one of the essential key factors to successful treatment with straight wire appliance (SWA). The aim is to reach a well finished orthodontic case with properly aligned crowns and roots, and leveled marginal ridges. Preadjusted edgewise bracket systems have given the orthodontists the chance to reach a step by step progression towards finishing. In contrast, standard edgewise appliances need abrupt stage of wire bending.(1)

Orthodontic brackets are bonded either intraorally with the direct technique or indirectly bonded on models. Direct bonding technique is a one-stage procedure, in which brackets are directly bonded to the patient's teeth chair-side using a bracket placement instrument. However, indirect bonding (IDB) technique is a two-stage procedure. In the first stage the brackets are placed on stone model of the patient's dentition; in the second stage the brackets are transferred to the patient's dentition by custom made transfer trays or jigs holding the brackets.(2)

Direct bonding technique has some drawbacks including poor visualization of posterior teeth landmarks such as long axis and marginal ridges(3), moreover the increased possibility of moisture contamination makes the operator may feel rushed or stressed during the procedure and increases chair side time. all these factors make the aimed ideal bracket positioning very difficult chair side.(4)

Many authors have discussed the comparative advantages of direct and indirect bonding for orthodontic brackets.(5-10) Theoretically, indirect bonding permits more accurate bracket placement because of the ability to see the bracket position from many different angles, but laboratory studies showed mixed results. Any benefit from better bracket placement with indirect bonding could be of no value with higher bond-failure rates than direct bonding. In vitro studies showed that both techniques had similar bond strengths under ideal conditions.(6,7,8) However, some in vivo studies showed that there is less control of the indirect-bonding environment, and indirect bonding has not been tested in vivo for bond strength or bracket-failure rates. Because it is technique sensitive, indirect bonding might lead to more bracket failures in an actual clinical environment.

IDB was introduced by silverman and cohen in 1972(9) to decrease chair side time and increase patient comfort. Their main concerns were the adhesive system and the transfer tray, different indirect bonding techniques were introduced with different tray materials.

Many studies have been conducted in order to test the indirect technique effectiveness. In fact, only few reports evaluated the clinical reliability of the indirect bonding technique.

Read and O'Brien(10) used a visible light-cured adhesive on foil mesh-based brackets for indirect bonding. Adequate clinical performance of this indirect bonding technique was concluded. Comparable rates of failure to another well-documented clinical trials of bonding adhesives and methods were noted. Twenty-nine brackets failed of the total 407 bonded brackets. All failures happened during the first 12 months of treatment. The total failure rate was 6.5%, and the

upper arch failure rate was 6.4% and the lower arch showed 6.7% rate of failure.

Bond strength was compared in an in vitro study by Sinha et al(11) between direct and two indirect bonding techniques. Results showed statistically significant difference between the

direct and the two indirect bonding techniques with higher bond strength of the direct compared to them. While, the bond strength between the two indirect bonding methods was not statistically significant.

An in vitro study by linn et at(12) has evaluated and compared the sites of bond failure and the shear bond strength of brackets bonded with three protocols, one direct and two indirect bonding material protocols. Results showed that neither of the three groups showed any significant difference in terms of bond strength, also the survival rate under normal forces of mastication and normal orthodontic force levels was higher than 90% for all groups.

Bond failure rate was compared between direct and indirect bonding techniques in a split mouth randomized clinical trial conducted by Thiyagarajah et al(13) over 33 subjects. The right side was indirectly bonded for group one and directly bonded for group two.1 year follow up was recorded for bond failures for the two groups. The overall Rate of bond failure was 14 brackets (2.5%). the results showed no significant difference regarding bond failure between the two techniques. Eight brackets were debonded with direct bonding technique while six brackets were debonded with indirect bonding technique. Moreover, the site of bond failure according to the tooth type was not affected by either of the two techniques.

An in vivo study conducted by deahl et al(14) has compared direct and indirect bracket bonding in terms of bond failure prevalence, rate of clinical visits and time of treatment between the two technique. The sample was collected from 11 orthodontic offices and 11 trained orthodontists had participated in this study. Direct bonding technique was used for 772 patients by 5 orthodontists with at least 2-year experience. While, indirect bonding technique was used for 596 patients by 6 orthodontists with at least 2-year experience with indirect bonding technique. Mean per-patient de-bond prevalence were 1.17% and 3.62% for direct-bonded brackets and 1.21% _3.81% for indirect-bonded brackets results showed no significant difference between both techniques regarding bond failure, time of the treatment and number of clinical visits.

Bozelli et al(15) has conducted a clinical study to compare the direct and indirect bracket bonding in term of the time spend for both techniques, The time spent in laboratorial and clinical steps in addition to prevalence of bond failure. A sample of 304 brackets were used for this study. After a 24-week follow-up, results showed that both techniques have incidence of loose bracket. While, the lower arch showed the greatest number of failures. The total time taken for direct bonding technique was smaller than that of the indirect bonding technique. However, the clinical step of indirect took less time than that of direct bonding.

Menini et al(16) carried out a clinical study to test the effectiveness of indirect bonding compared to direct bonding technique regarding the number of bond failure occurred . First group of patients was directly bonded while, the second group was indirectly bonded. Rate of bracket failure was recorded over a period of 15 months. Same type of brackets, molars tubes and adhesive systems were used for both groups. The results showed no significant difference between direct and indirect bonding techniques. Either of the two techniques showed any differences in the upper arches, while a

significantly larger number of bond failure occurred in the lower arch (9.64% of the total bonded bracket). With comparing the posterior segments of the mandibular arch there was difference in bond failure rate, with a significantly higher number of detachments in group B, bonded with the indirect technique.

A study by Vijayakumar et al(17) also evaluated the bond failure rates between indirect and direct bonding methods. In addition, they evaluated the effect of a single vacuum formed transfer tray and the use the of a single light cure adhesive on bond failure rates in clinical conditions. A split mouth study design was used for 30 patients, two groups were randomly separated (Group A and Group B). Bond failure rate was evaluated for both groups over a period of 6 months. the results showed that direct bonding showed overall more bond failure. Direct bonding showed more anterior bracket failure than indirect while, indirect bonding showed more posterior bracket failure than direct bonding. However, more bond failure rates were found with lower incisors and premolar brackets followed by upper premolars and canines in terms of single tooth bond failure for both techniques.

An in vitro study conducted by Tavares et al (18) in 2017, compared between direct and indirect bonding techniques in terms of shear bond strength (SBS), adhesive remnant index (ARI) , and change of color between the two techniques they also compared (SBS), (ARI) and change of color between self-etched and acid etched primers, the study was conducted on 70 bovine incisors and the results showed that both direct and indirect showed similar results and all the primers showed satisfactory adhesion strength.

In 2018, Demirovic et al (19) has conducted an in vitro and in vivo study to compare the shear bond strength of orthodontic brackets bonded with direct and indirect bonding techniques. Rate of survival was evaluated over a period of 6 months. The shear bond strength between direct and indirect bonding methods showed no statistically significant difference. Also, both methods produced similar scores of adhesive remnants on teeth. Furthermore, no significant differences in bracket survival rates between direct and indirect bonding was detected. So, in terms of shear bond strength, adhesive remnant on tooth surface, and survival rates both indirect and direct bonding techniques were clinically considered of equal value.

In 2018, Pamukçu et al(20) evaluated orthodontic indirect bonding resins both in-vitro and in vivo, shear bond strength (SBS) was evaluated in vitro and bond failure rates was evaluated in vivo. After twelve months of follow up they found that bond failure rates between groups didn't show any significance and failure rates of the two resins found to be

suitable for clinical use , the conclusion in the in-vitro study was that the shear bon strength with chemically-cured indirect bonding resin was lower than flowable light-cured resin and the control group.

2018,Yildirim (21) compared the effects of indirect and direct bonding techniques on orthodontic treatment procedure and results. Indirect bonding was significantly having shorter chair side time when compared to direct bonding in the clinical stage. Moreover, better marginal ridge and total scores were shown with indirect bonding. While plaque accumulation, formation of white spot lesions, bond failure,

and additional arch wire bending and bracket repositioning were found to be similar with both techniques.

A systematic review and meta-analysis was performed to test the Effectiveness, efficiency and side effects of using direct or indirect bonding technique in orthodontic patients (22) the trials included were assessed with the aid of cochrane risk of bias assessment tool considering randomized controlled trials of both techniques, considering bracket placement accuracy and oral hygiene there weren't any significant difference between both techniques, less clinical time but more total working time was found with the indirect bonding technique due to its extra laboratory steps, regarding bond failure rates meta-analysis hadn't show any significant difference between the two techniques.

Materials and methods:

1. Study design and sample selection

This current study was a randomized controlled trial with a split mouth design. The allocation ratio was 1:1. Fifteen patients (5 males and 10 females) were selected for this study from patients attending the clinic of Orthodontic Department, Faculty of Dentistry, Mansoura University. Ethical approval was obtained from Dental Research Ethics Committee, Faculty of Dentistry, Mansoura University. Subjects were included if they

required orthodontic treatment with fixed orthodontic appliances. All permanent teeth are erupted except for last molars. Absence of any enamel defect that may affect the bonding. No severe crowding that may alter proper bracket placement. Age range between 14 and 25 years old. Good oral hygiene. Free of gingivitis or periodontal disease. Subjects who fulfilled the inclusion criteria were enrolled into the study and consecutively allocated a number at the time of record collection.

Based on our pilot study, a sample size of 262 units (131 per group) is required to achieve a power of 90 % to detect a small to medium effect size of d = 0.4022409 using two-sided independent samples t-test at a significance level of $\alpha = 0.050$ as calculated by G*Power software (version 3.1.9.4). An over sizing of the sample was done assuming a possible bond failure of about 10% and to increase the validity of the results. This study was conducted on 300 units (150 per group). Fifteen patients in need of upper and lower full arch fixed appliance were enrolled in this study.

A full mouth scaling and polishing with a rubber cup and polishing paste was done. Any chipped incisal edges or cusp tips of dentition were smoothed. Oral hygiene measures instructions were given to all patients.

2. Study procedures.

Two indirect bonding techniques were used; Digital computer aided technique as the intervention group, and manual traditional technique as the comparative group. Each technique included 3 stages; clinical stage I, laboratory stage, clinical stage II.

2.1. The traditional technique (the comparative).

2.1.1. Clinical stage I.

Rubber base impression was taken* and poured in extra hard stone**. model. The models were trimmed to horse show shaped arches.

2.1.2. Laboratory stage.

Regarding brackets positioning guidelines on the working models, vertical reference lines were drawn with a black pencil representing the long axis of each tooth with the aid of panoramic Xray. Two horizontal reference lines were drawn. The first line was marked with a red pencil representing the inter-marginal ridge reference line from the 1st permanent molar to the canines. The second line was marked with a black pencil at the center of the first molar. The distance between the two lines was measured with a bow divider and duplicated at the second premolar, first premolar and canine. Measurements were transferred to the lateral and central incisors with the aid of Boone gauge.(23,24)

Brackets* were bonded to the working model according to Roth prescriptions with a single thin layer of water-soluble Tacky glue adhesive**. The slots were centered on the black horizontal and vertical reference lines. Brackets were firmly pressed on the model to get rid of any excess adhesive. Any adhesive remnants were removed all around the brackets. Brackets were then allowed to set for at least 5 minutes and then checked for retention on the cast.

The models were coated with a thin layer of insulating agent. Soft 1mm thick vacuum sheet*** was vacuum-formed over the model. All areas cervical to the brackets were blocked out with wax. Then, hard 1 mm thick vacuum sheet**** was pressed over it. Pressure molding machine***** was used to heat the sheet and before pressing it on the model. The machine has standardized time and temperature for each sheet thickness by scanning the sheet code.

The cast with the sheet then were placed in a rubber bowl filled with water for 10 minutes to dissolve the water-soluble glue. The assembly was then removed from water and the tray was detached from the cast. Excess material was trimmed away up to 1mm apical to the gingival margin. The tray was cleaned with a clean tooth brush then air dried. Vertical slots were added on the soft tray with sharp scissors above mesial and distal bracket wings to allow the excess composite to get from it during bonding.

2.1.3. Clinical stage II.

Teeth were isolated with a cheek retractor and etched with 37% phosphoric acid etch for 20 seconds. Teeth were then rinsed with water for 20 seconds to ensure complete etchant

removal, and air-dried until they appeared dull and frosty. Proper isolation with cotton rolls was performed.
Primer was added to teeth surface then small amount of composite* was applied to the base of each bracket in the tray. Tray was firmly seated intraorally and the patient was asked to bite through the rolls to fix the tray in place during curing. Light cure was applied for 30 seconds for each tooth using 1000 mW/cm light cure** from the last premolar and moved anteriorly.
Hard tray was first removed by smooth tip instrument, then the soft tray was pealed from the teeth. The previously opened slits aided to decrease the tray retention then it was fully removed by rolling it lingually. The bond strength of each bracket was tested by applying finger pressure to it. Any bracket which failed to bond were directly bonded and rolled out of the study.
2.2. The digital computer aided technique (the intervention).
2.2.1. Clinical stage I.

• Intraoral scanning was done to obtain digitalized dentition for each patient by intraoral scanner***. The initial position of the teeth was captured by the scanner. The file was exported from scanner software and imported to Ortho Analyzer software* to plan and construct a 3D working model for virtual bracket placement.
2.2.2. Laboratory stage.
2.2.2.1. Software planning.
The file model was imported to Ortho Analyzer software, and then trimmed to imitate the stone models. Occlusal plane was then established for the model. Upper and lower teeth were defined by segmentation of the teeth from the cast, by indicating the mesial and distal marginal ridges of the posterior teeth and the mesial and distal contacts of anterior teeth. The tooth structures were then outlined by the software and the gingival margins were defined. This allow the software to differentiate between teeth and gingiva. After segmentation was complete, any needed modification and sculpting of the tissue and teeth were done.
Long axis of teeth was performed. Facial axis point (FA) points were defined. These points represent the future exact place of the brackets. Both can be modified during the segmentation process. The software defaults were accepted and final bracket positioning was done later in indirect bonding studio
Preadjusted edgewise brackets with 0.022-inch slot** were then virtually placed on incisors, canines and premolars of two opposite quadrants. The bracket position can be modified to the desired position and any adjustments can be done at this stage. Evaluation of bracket position was done from many different angels. Computer measured incisal edge distance was considered as a good guidance to ensure the most accurate leveling and occlusal coupling. Final bracket positions were approved and validated. The master model was then saved
The master model with attached brackets was then opened on 3 shape Appliance Designer*. "Vacuum Pressed Transfer Media" was selected as the production equipment for new appliance. Block-out angle was set to -5 degree. Retention amount was set to 0.25 mm. After confirmation, the bracket transfer medium model color was changed and the prescribed block-outs were visible.
2.2.2.2. Model printing.
The digitalized models with the attached brackets were then exported from Appliance designer to desktop in stereolithography format. The saved STL files represented the preoperative image for computer aided technique (image I) for digital technique. Within the printing software. The models were oriented at about 35-degree angle with the supports to have few supports on the bracket wings and hooks to avoid their distortion on the model. When the print was complete, the model was washed in an isopropyl alcohol path then post cured for two minutes
• 2.2.2.3. Transfer tray construction.
A double thermoformed transfer tray was then constructed over the model as with manual quadrants. The first layer was flexible sheet of 1 mm Bioplast material while the second layer was hard 1 mm Duran material. Excess material was cut from the tray to the extent of the printed quadrants, the tray was then removed from the printed cast and the real brackets used in the software were inserted into their indentations into

the tray with adequate retention to ensure accuracy, The indirect bonding tray was then ready to be transferred to the patient.

2.2.3. Clinical stage II
Teeth of the aimed quadrant were isolated and etched, rinsed and dried then primer is added. The tray was then seated intraorally and light cure was applied. The hard-outer tray layer is first removed then the soft.
3. Outcome
was to record the bond failure of orthodontic brackets immediately after detachment of the transfer tray and after wire ligation. After tray was detached from the brackets intraoral scanning was done. Round nickel titanium wire 0.012 was inserted into both arches. An elastomeric ligature was tied to each bracket. Any failed bracket was recorded and written in a table form for bond failure assessment over a period of three months.
4. Randomization. (allocation)
This study was a randomized controlled trial with a split mouth design. The intervention group was represented by vacuum trays over 3D printed casts with computer aided bracket placement. While, the comparative group was represented by the vacuum formed trays over regular stone casts with traditionally bonded brackets. Both trays were used for indirect brackets bonding to the patient's dentition.
5. Statistical analysis:
5.1. Software used:
Data was entered and analyzed using IBM-SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

5.2. Exploring and presenting data:
Qualitative data:

Qualitative data was expressed as frequency (percentage) and compared by Chi-Square or Fisher's exact test.

5.3. Significance level:

For any of the used tests, results were considered as statistically significant if p value ≤ 0.050.

5.4. Graphs:

Appropriate charts were used to graphically present the results whenever needed.

Results

This study involved 300 teeth divided into two groups

Group 1: traditional, n=150

Group 2: Digital, n=150

Of these 300 teeth, there were 9 initial failures; 4 brackets of method I (traditional) (2.7%) and 5 brackets of method II (computer aided) (3.3%). This difference was statistically insignificant (Fisher's exact test, p=1.000). At 3-months follow up, 8 additional failures occurred; 2/145 in digital group (1.4%) and 6/146 in manual group (4.1%). This difference was also statistically insignificant (Fisher's exact test, p=0.282).

Total bracket failure was counted for each group for further statistical evaluation. Seventeen of the total 300 brackets that were bonded failed or detached, the complete failure rate was (5.7%). For group I, there were 10 brackets while for group two, there were 7 brackets (table….).

Table 1. Total bond failure rate for traditional and computer aided indirect bonding groups.

Bond failure	Total	Group I (Traditional)		
(n=150)	Group II (Computer-aided)			
(n=150)	□2	P value		
Yes	17 (5.7%)	10 (6.7%)	7	(4.7%)
	0.561	0.454		
No	283 (94.3%)	140 (93.3%)	143	
(95.3%)				

Data expression: Frequency (Percentage). P value: Chi-Square test.

This table showed overall bond failure rate was 5.7%; it was slightly higher in control (Traditional, Manual) group vs intervention (Computer-aided) group; 6.7% vs 4.7%, respectively and this difference was not statistically significant (p = 0.454).

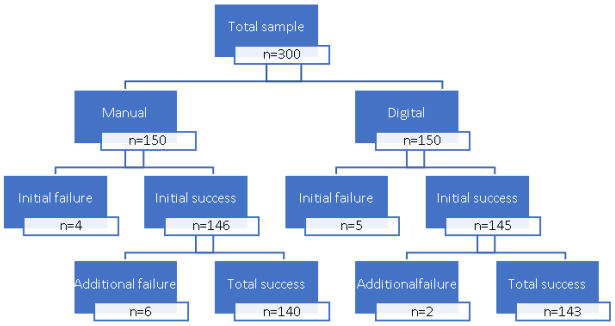

Figure 1. Flow chart for the studied teeth.

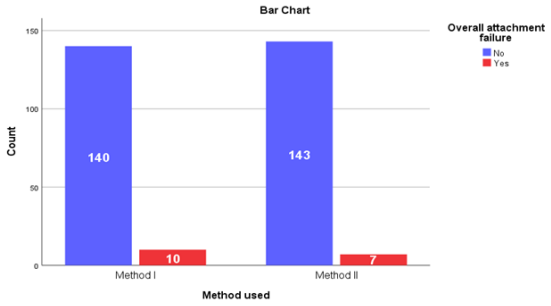

Figure 2. Overall bond failure rate for both methods

Discussion

Orthodontic brackets are bonded either intraorally with the direct technique or indirectly bonded on models. Direct bonding is more popular technique than indirect bonding by most of orthodontists. With the introduction of indirect bonding technique, the chance to obtain more accurate bracket positioning has increased; due to the ability to view the brackets from different angels. The difficulties of inaccessibility and long appointments associated with the direct bonding technique can be eliminated. Moreover, the

reduction of the need for bracket repositioning and arch wire bending during the treatment.(25) Indirect bonding showed great efficiency and effectiveness over the years in terms of accuracy and reducing chair side time for both operator and patient.(26,27)

Bond failure rate of direct and indirect bonding techniques have been compared for many decades with no significant statistical difference between the two techniques. (5,13,17) In this study, bond failure rate has been compared between a new approach of computer aided indirect bonding technique and another traditional indirect bonding technique. Split mouth design was used to avoid the bias between right and left sides and between upper and lower bonding

Our aim in this study was to calculate the rate of bond failure of computer aided (digital) and traditional (manual) indirect bonding techniques and also to compare the failure rate between the two methods.(28) When comparing the bond failure between the two indirect bonding techniques, the differences were statistically insignificant. This is of clinical

relevance because any benefit from better bracket placement with indirect bonding could be of no value with higher bond-failure rates than direct bonding.

The results of the current study for the digital and manual techniques were (4.7% ,6.7%) respectively. The bond failure rate was found to be <10% for over-all comparison, which was clinically acceptable for both methods, bond failure rate below 10% is clinically acceptable as suggested by Cal.Neto et al.(29) These results are in agreement with Deahl et al(14) and Thiyagarajah et al(13)that found no difference in detachment rate between direct and indirect bonding techniques with a comparable ratio for our study results (3.54% for direct technique, 5.79%for indirect one).

The percentage of bond failure reported in the present study (6.7% for method I, 4.7% for method II) is higher for both techniques than the percentage reported by Deahl (1.21%and 3.81%, respectively) as well as those reported by Thiyagarajah 2.2% for indirect bonding technique. The reasons of this difference could be the type of bracket and adhesive system, procedure used for the transfer tray construction, number of patients included in the sample and study design.

Conclusions

- Both indirect bonding methods were considered effective with-out compromising on the bonding procedure.
- Rate of bond failure for both methods was considered clinically accepted
- No statistically significant difference between the two methods as regards attachment failure.

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