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ORIGINAL RESEARCH

Indirect versus Direct Bonding—A Shear Bond Strength Comparison: An *in vitro* Study

M Swetha, Vinaya S Pai, N Sanjay, S Nandini

ABSTRACT

Aim: The process of bonding orthodontic appliances to the enamel surface of the teeth has come to the forefront as a major improvement in bonding techniques. The purpose of this study is to compare the shear bond strength of stainless steel orthodontic brackets bonded using conventional direct bonding and indirect bonding as described by Thomas.

Materials and methods: Forty sound human premolars were divided into two groups of 20 each. Group I samples were bonded directly on the tooth surface using concise two paste adhesive system after etching and drying. Group II samples were bonded indirectly on the tooth surface according to Thomas indirect bonding technique using concise two paste adhesive system. The stored specimen was tested for shear bond strength in an Instron universal testing machine at a crosshead speed of 0.5 mm/minute. Data obtained were subjected to statistical analysis.

Results: The results showed that there was no statistically significant difference in the shear bond strength between direct and indirect bonding techniques. Chi-square test showed that there were significant differences among the adhesive remnant index scores between direct and indirect bonding groups.

Conclusion: *In vitro* shear bond strength comparison between direct and indirect-bonded attachments showed no significant difference between the two groups. Bond strength obtained with Thomas indirect bonding technique was comparable with direct bonding technique.

Clinical significance: Thomas indirect bonding technique can be used for bonding of the posterior teeth, where the risk of moisture contamination is high during bonding.

Keywords: Direct and indirect bonding, Concise two paste system, Shear bond strength, Adhesive remnant index.

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INTRODUCTION

It has been widely recognized that 'accurate bracket positioning' is of utmost importance in the efficient application of biomechanics and in utilizing the full potential of a preadjusted edgewise appliance, thereby minimizing the need for prolonged tedious finishing and detailing procedures.[1]

The present scenario is the art of bonding. Dr George Newman was the first to introduce the technique for bonding brackets directly to tooth enamel using epoxy resin.[2] With the introduction of several bonding materials, different bonding techniques have evolved with improved bond strength and handling characteristics. The direct bonding of orthodontic brackets has revolutionized and improved the clinical practice of orthodontics. Both direct and indirect bonding procedures most often use Bis-GMA (bisphenol A-glycidyl dimethacrylate) resin which was introduced by Rafael Bowen in the year 1965.[3]

The problem encountered with direct bonding whether light cured or chemically cured is prolonged chair side time. Also, the bracket positioning in posterior segment and on malaligned teeth may be affected due to poor access. In case of lingual orthodontics, limited access and visibility, greater variation in lingual surface morphology, short lingual crown height, wide range of labiolingual thickness, and so on contribute to inaccurate bracket placement with direct bonding technique.[4]

Another problem encountered by the clinicians during treatment with direct bonding technique is bracket failure.[5] Various factors which cause bond failure have been cited such as inappropriate etching, inadequate application of bonding agent, improper bonding technique used, design of bracket base, moisture contamination and so on.

Bond failure rates of 4.7% for the light cure and 6% for the chemical cure materials with direct bonding technique have been reported.[6] To overcome all these deficiencies, a major breakthrough is the introduction of indirect bonding technique.

Indirect bonding procedure was introduced by Silverman, Cohen et al in 1972, so as to overcome the problems of direct bonding procedure and to make an attempt to place brackets on teeth more accurately and efficiently.[7] In 1979, Thomas introduced a simple and efficient way of bonding the brackets which is said to be the foundation for contemporary indirect bonding. This method seemed to correct the deficiencies of direct bonding technique and perhaps simplify posttreatment debonding also.[8]

The aim of the present study is to compare the shear bond strength between direct and indirect bonding techniques using concise—two paste self-cure adhesive system.

MATERIALS AND METHODS

A total of forty sound human premolars extracted for orthodontic treatment were randomly selected for this study from the Department of Oral and Maxillofacial Surgery, Bangalore Institute of Dental Sciences, Bengaluru. Selection criteria included teeth with good morphology, intact buccal enamel surface, devoid of any developmental defects, caries free, no cracks due to extraction forceps and the teeth were not subjected to any pretreatment chemical agents, such as alcohol, formalin or hydrogen peroxide. These teeth were thoroughly cleansed of any soft tissue tags and blood. All the teeth were stored in sodium chloride solution for a maximum of six months before testing.

For all the forty teeth selected for the study, the apical one-third of root was sectioned and divided randomly into two groups containing 20 teeth in each group. Each group was color coded with different colors for proper identification. Stainless steel brackets of Gemini series Roth-0.022 inch slot (3M unitek, Monrovia, Calif) were used in the study. The surface area of the bracket base was 9.806 mm^2 as per the specification given by the manufacturers.

Sample Preparation for Testing Shear Bond Strength—Direct Bonding Technique (Group I)

The teeth in the group I were mounted using cold cure acrylic resin poured in metal rings for direct bonding. The mounted assembly was placed in the dental surveyor (Strong Taegu, Korea) to check the parallelism (Fig. 1). The brackets were directly bonded using concise two paste self-cure adhesive system (Fig. 2).

Each surface was treated with 37% phosphoric acid liquid for 60 seconds, rinsed thoroughly with copious amount of water and subsequently dried with oil-free compressed air. A thin layer of mixed concise unfilled (liquid A and liquid B) resin was applied to etched enamel surface in each specimen. Equal amount of concise paste A and B was then dispensed on the mixing pad, each paste was diluted by mixing with appropriate amount of respective concise unfilled liquid A and liquid B resin and mixed according to manufacturer's instruction. The mixed adhesive was then applied to the bracket base which was subsequently placed onto the prepared enamel surface, at a predetermined area with bracket positioner. The teeth in group I were color coded with blue color for proper identification (Fig. 3).

Fig. 1: Surveyor assembly to check the parallelism

Fig. 2: Concise two-paste adhesive material kit

Fig. 3: Twenty group I samples (direct bonding)

Sample Preparation for Testing Shear Bond Strength—Indirect Bonding (Thomas) Technique (Group II)

An accurate alginate impression for each sample in the group II was obtained. After impression material sets, the mould space obtained was then poured with the die stone. After setting and drying the models, each model and its respective die were mounted on round plaster blocks with a central depression made with modelling wax. All specimens and their corresponding models were numbered from 1 to 20 for easy identification. The models were painted with a thin layer of separating medium and allowed to dry. Equal amounts of concise diluted pastes A and B were mixed to bond each bracket accurately to the model at predetermined position with reverse tweezer. After 60 minutes, an individual silicone positioner was formed on each specimen by homogeneous mixing of base paste and catalyst paste of polyvinyl siloxane material (putty consistency) and was allowed to bench cure according to the manufacturer's instructions. Each model-positioner complex was placed in hot water for 15 minutes to dissolve the separating medium and thus the adhesive model bond, the positioner with its embedded bracket was separated from the model, and the bracket pad was cleansed with running warm water.

The actual natural teeth enamel surface was then cleansed with pumice and water slurry with a dental rotary handpiece and brush for 5 seconds and thoroughly rinsed with a stream of water for 10 seconds and dried with oil-free compressed air. Each surface was treated with 37% phosphoric acid liquid for 60 seconds, rinsed thoroughly with copious amount of water and subsequently dried with oil-free compressed air. Concise unfilled liquid resin A was then applied to the etched tooth surface and concise unfilled liquid resin B to the bracket base in the positioner which was then placed over its corresponding tooth, held with light pressure for 2 minutes. All the silicone positioners were peeled from the specimens after 5 minutes of placement. The bracket-adhesive-tooth interface was inspected visually for voids, which were sealed with an additional mixture of concise unfilled liquid resin A and B.

All the bonded specimens were then removed from the plaster blocks and mounted using cold cure acrylic resin poured in metal rings for indirect bonding technique similarly as explained in the direct bonding procedure. Teeth in the group II samples were color coded with red color for proper identification (Fig. 4).

The bonded 40 specimens were stored in distilled water at 37°C for 24 hours before testing for shear bond strength.

Fig. 4: Twenty group II samples (indirect bonding)

Evaluation of Shear Bond Strength

A universal testing machine (Instron-4667) (Fig. 5) with a load cell carrying 30 KN was attached to the machine. A crosshead speed of 0.5 mm/minute was used to debond the brackets. For measuring the shear bond strength, the prepared metal ring was fixed to the aluminum jig (Fig. 6) which was positioned in the lower crosshead, with the long axis of the tooth and the bracket base parallel to the direction of force load applied. A wire loop was made using ligature wire and the ends of the wire were gripped in the upper jaw (crosshead) and under the gingival tie wings by adjusting the crosshead (Fig. 7). The crosshead moved at a uniform speed of 0.5 mm/minute. The load was progressively applied till the bracket got detached from the tooth surface and the reading for every specimen was recorded in kilograms and then converted into megapascals (Mpa) by using the following formula,

$$\text{Shear bond strength in megapascals} = \frac{\text{Debonding force in kilograms} \times 9.81}{\text{Bracket base area } (9.806 \text{ mm}^2)}$$

Gravitational constant = 9.81

Fig. 5: Instron universal testing machine (model no. 4667)

Fig. 6: Aluminum jig and two samples

Fig. 7: Specimen mounted for shear bond strength testing on Instron machine

Adhesive Remnant Index (ARI)

After bond failure of the brackets, the surfaces of the teeth were examined to assess the adhesive remnant index (ARI), which describes the amount of adhesive remaining on the surface of the tooth. Amount of residual adhesive was classified using ARI developed by Artun and Bergland, which is as follows:

0 = No adhesive is left on the tooth surface.
1 = Less than half of the adhesive left on the tooth surface.
2 = More than half of the adhesive left on the tooth surface.
3 = Entire adhesive left on the tooth surface, with a distinct impression of the bracket mesh.

RESULTS

The descriptive statistics of two groups clearly showed that both the direct and indirect bonding groups had the following bond strength values (Table 1 and Graph 1):

- *Group I (Direct bonding):* The mean shear bond strength was 15.11 ± 3.98 MPa.
- *Group II (Indirect bonding):* The mean shear bond strength was 15.65 ± 4.18 MPa.

On comparing the mean shear bond strength of group I and group II by Student's t-test, there was no statistical significant difference between the two groups (Table 2 and Graph 2).

There was a statistically significant difference in the ARI scores (Chi-square test) between direct (group I) and indirect (group II) bonding groups ($p < 0.05$). Fifty-five percent of

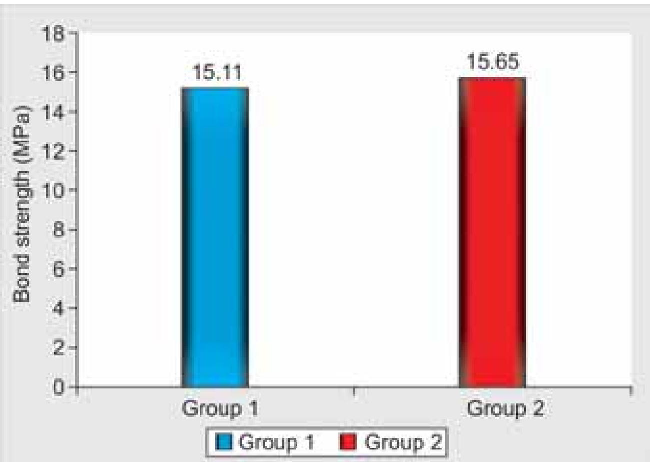
Table 1: Shear bond strength of the samples tested in Megapascals (MPa)

S. no.	*Group I (Direct bonding)*					*Group II (Indirect bonding)*				
	SBS (kg)	*SBS (MPa)*	*Range (MPa)*	*Mean (MPa)*	*ARI score*	*SBS (kg)*	*SBS (MPa)*	*Range (MPa)*	*Mean (MPa)*	*ARI score*
1	8.93	8.93	8.37 to 23.03	15.11	2	14.17	14.17	8.20 to 23.36	15.65	1
2	13.85	13.85			2	19.10	19.10			1
3	17.48	17.48			3	16.46	16.46			1
4	11.52	11.52			3	20.13	20.13			1
5	13.29	13.29			3	18.50	18.50			2
6	18.20	18.20			3	11.76	11.76			1
7	14.58	14.58			3	23.36	23.36			1
8	8.37	8.37			2	9.42	9.42			1
9	20.05	20.05			2	17.40	17.40			2
10	14.34	14.34			3	17.90	17.90			2
11	10.39	10.39			2	15.50	15.50			1
12	12.72	12.72			3	20.29	20.29			1
13	14.74	14.74			3	9.34	9.34			1
14	12.40	12.40			3	14.09	14.09			3
15	16.83	16.83			1	12.24	12.24			1
16	22.63	22.63			2	8.20	8.20			0
17	12.48	12.48			3	16.91	16.91			1
18	23.03	23.03			1	14.50	14.50			1
19	10.87	10.87			3	12.97	12.97			0
20	15.46	15.46			2	20.78	20.78			2

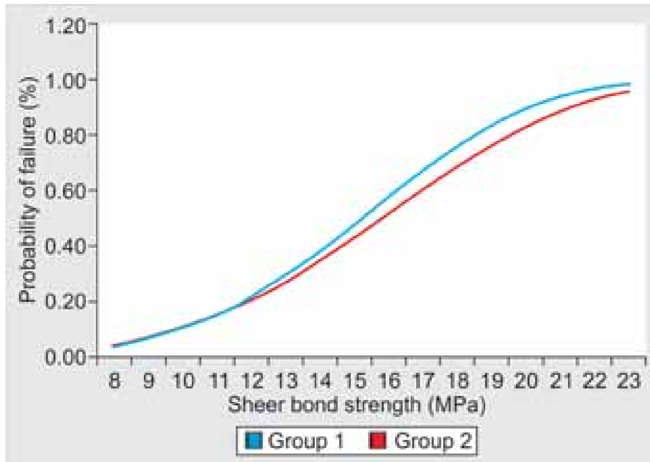
Table 2: Students' t-test for comparison of mean shear bond strength of samples between group I (direct bonding) and group II (indirect bonding) in MPa							
Groups	*N*	*Mean*	*Std. deviation*	*Minimum*	*Maximum*	*t-value*	*p-value*
Group 1	20	15.11	3.98	8.37	23.03	–0.421	0.676
Group 2	20	15.65	4.18	8.20	23.36		

p = 0.676 > 0.05 (not significant)

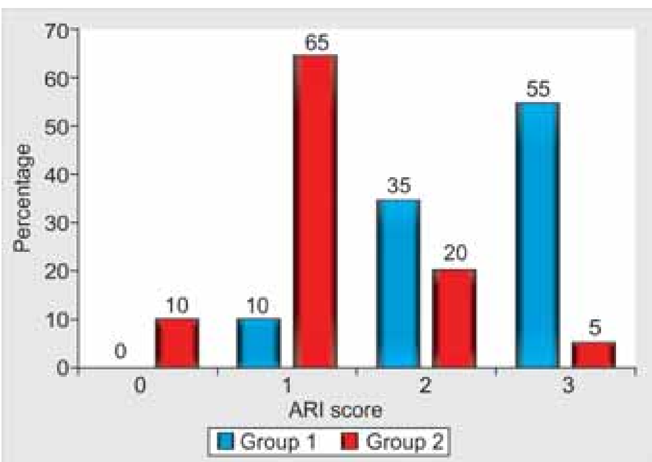
Table 3: Distribution of adhesive remnant index (ARI) scores between groups					
Groups	*ARI score*				*Total*
	0	1	2	3	
Group 1	—	2	7	11	20
	—	10.0%	35.0%	55.0%	100.0%
Group 2	2	13	4	1	20
	10.0%	65.0%	20.0%	5.0%	100.0%



Graph 1: Comparison of mean shear bond strength between the study groups



Graph 3: Weibull analysis to examine the probability of bond failure



Graph 2: Distribution of ARI scores between the study groups

the samples in the group I showed ARI score 3, where entire adhesive remained on the tooth surface after debonding. In group II, 65% of the samples showed ARI score of 1, where more than half of the adhesive remained on the bracket base.

Weibull analysis was undertaken to examine the probability of failure (Table 3 and Graph 3). The curves showed that probability of bond failure for direct bonding technique was 10% at 9 MPa and 90% at 20 MPa, whereas probability of bond failure for indirect bonding technique was 10% at 10 MPa and 90% at 22 MPa. Thus, there was not much difference in the probability of bond failure at a given stress (MPa) between group I and group II samples.

DISCUSSION

Several major developments have occurred during the past few years in the field of orthodontics that has made the routine bonding of orthodontic attachments feasible. Direct bonding has been in practice since 1965, whereas, indirect bonding was first introduced in 1972. Since their introduction to orthodontics, both the direct and the indirect methods have undergone refinements in technique and materials. Ideally, in both the methods, the bond strength should be optimum. Reynolds stated that the bond strength for the brackets should be in the range of 5.9 to 7.8 Mpa.[9]

Our results showed that mean bond strength for group I and group II are well over this clinically acceptable range. These findings are similar with several previous studies[3,8] that report that the mean shear force required to fracture the brackets bonded with direct and indirect bonding methods using Thomas technique were statistically not significant.

Our results also show that in group II, 65% of the samples showed ARI score of 1, where more than half of the adhesive remained on the bracket base. These findings are in agreement with studies,[10,11] done using a chemically cured primer (Sondhi Rapid set) and Transbond XT (adhesive) on unused brackets as well as thermocycled brackets for indirect bonding. In our study, bond failure of brackets in group II (indirect bonding) occurred at enamel-adhesive interface. This indicates lesser enamel damage and quicker clean up after debonding. It is, however, to be noted that although group II had a lower ARI score when compared with group I, the Pearson correlation coefficient determined that there was no correlation between bond strength and amount of adhesive remnant remaining ($p < 0.05$).

Furthermore in this study, Weibull analysis indicated that group II had 10% of probability of bond failure at 10 MPa and 90% at 22 MPa which indicates good bond strength within normal orthodontic forces.

LIMITATIONS OF THE STUDY

This study has been an *in vitro* study. Every effort has been made to simulate the clinical conditions as close as possible, the advantage being the use of human premolar teeth, which adds on to its authenticity. At best, information obtained from *in vitro* study can be used as means of rank ordering performance and gives an indication of likely clinical performance. Although, this data suggests that indirect bonding with a chemical-cured adhesive could provide similar bond strength as in direct bonding. This was an *in vitro* investigation and hence it is necessary to compare these results with those obtained within the oral environment. Also, SEM would give a clearer picture of the enamel surface after debonding.

CONCLUSIONS

From this study, following conclusions were made:

1. *In vitro* shear bond strength comparison between direct- and indirect-bonded attachments showed no significant difference between the two groups.
2. There were statistically significant differences in bond failure site (ARI) between direct and indirect bonding techniques.
3. Concise two paste adhesive system showed clinically satisfactory bond strength with both direct and indirect bonding techniques.
4. In direct bonding technique, bond failure occurred at the bracket composite interface with maximum adhesive remaining on the tooth surface, while in indirect bonding technique, bond failure occurred at the enamel composite interface with maximum adhesive remaining on the bracket base.
5. Neither group I nor group II showed any correlation between bond strength and amount of adhesive remaining.
6. Bond strength obtained with Thomas indirect bonding technique was comparable with direct bonding technique.
7. Thomas indirect bonding technique results in reduced amount of resin flash, diminished risk of voids that might weaken the bond and causing plaque accumulation, minimal adhesive thickness, permits greater working time with the adhesive materials, easier clean up of excess material after debonding and reduces the amount of enamel damage.
8. Thomas indirect bonding technique can be used for bonding of the posterior teeth, where the risk of moisture contamination is high during bonding.

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ABOUT THE AUTHORS

M Swetha (Corresponding Author)

Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Bangalore Institute of Dental Sciences and Postgraduate Research Center, 5/3 Hosur Road, Bengaluru-560027, Karnataka, India
Phone: +919886127643, e-mail: swethaortho@yahoo.com

Vinaya S Pai

Principal, Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Bangalore Institute of Dental Sciences and Postgraduate Research Center, Bengaluru, Karnataka, India

N Sanjay

Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Rajiv Gandhi College of Dental Sciences, Bengaluru Karnataka, India

S Nandini

Professor, Department of Orthodontics and Dentofacial Orthopedics Bangalore Institute of Dental Sciences and Postgraduate Research Center, Bengaluru, Karnataka, India