Shear Bond Strength of Ceramic Brackets with Different Base Designs: An in-vitro Study

Dr Gaurav Chaudhary,[1] Dr Pawan Kumar Chandra,[2] Dr Rakesh Sharma,[3] Dr P Narayana Prasad,[4] Dr Sonia Gera[5]

[1]Senior Lecturer, [4]Professor, [5]Postgraduate Student

Dept of Orthodontics, Seema Dental College, Rishikesh, India

[2, 3]Professor, Dept of Orthodontics, ITS-Center for Dental Studies & Research, Muradnagar, India

Correspondence: *Dr Gaurav Chaudhary;* *Email:* *chaudharydrgaurav@gmail.com*

ABSTRACT

Objective: To evaluate the influence of bracket base designs on shear bond strength of ceramic brackets bonded to natural teeth and to determine the common site of bond failure.

Materials & Method: 120 therapeutically extracted maxillary first premolars were divided into six groups of 20 samples each and were mounted in resin blocks. Each sample was bonded with bracket of that particular group and subjected to thermocycling. The shear bond strength was measured using Universal Testing Machine. After debonding, the teeth and brackets were examined under stereo-microscope for adhesive remnant index.

Result: Ceramic brackets with ball base design (Group A) yielded statistically highest shear bond strength followed by microcrystalline base (Group D), dimple base (Group E), mesh base (Group C) and dove tail base (Group B) design. Ceramic brackets yield higher bond strength than metal brackets (Group F) irrespective of base design. Insignificant difference was seen between Group A and Group D and between Group B and Group C. Bond failure between adhesive and bracket (Type 3) was seen in 80% of the brackets with ball base design and bond failure between adhesive and bracket (Type 1) was seen in 80% of brackets with dove tail base design.

Conclusion: Bracket base design is an important consideration for shear bond strength. Base design with more number of undercuts offer higher shear bond strength. Ceramic brackets with more number of mechanical undercuts were less likely to bond failure at adhesive bracket base interface and vice versa.

Key words: adhesive bracket-base interface, adhesive remnant index, microcrystalline base, shear bond strength

INTRODUCTION

Ceramic brackets were introduced in 1987 as a more esthetically pleasing alternative to stainless steel brackets.[1] Two types of ceramic brackets are available according to their distinct differences during fabrication, they are: polycrystalline and monocrystalline (single-crystal) aluminas.[2,3] Both polycrystalline and monocrystalline ceramic brackets possess various base designs such as grooves, beads, or round pits for the purpose of mechanical interlocking between the brackets and the teeth.[4] As bracket bases do not chemically bond to enamel or resin, efforts are made to improve mechanical retention using various designs.[5]

Despite various modifications and innovation in technologies, still there is a lack of consensus regarding the effect of bracket base design on shear bond strength (SBS) when tested under conditions simulating clinical use of those brackets.

The objective of the study was to evaluate the influence of bracket base designs on shear bond strength of ceramic brackets bonded to enamel surfaces of extracted teeth. The specific objective were:

1. To compare shear bond strengths of various ceramic brackets with different base designs and that from the stainless steel brackets.
2. To determine the site of bond failure for each sample group.

MATERIALS AND METHOD

The study was conducted in the Department of Orthodontics, ITS-CDSR, Muradnagar, Ghaziabad and ITS Engineering College, Noida. The study was conducted on 120 extracted human maxillary first premolars. All teeth used in the study were extracted therapeutically for orthodontic treatment and were stored in 0.1% thymol solution. The teeth were washed, debrided and then stored in distilled water to prevent dehydration and bacterial growth. The teeth were cleansed and then polished with non-flouridated pumice and rubber prophylactic cup for 10 seconds.

Table1: Distribution of Samples

Group	Type of bracket with base design	No. of Sample	Labelling
A	Ceramic brackets with ball base design	20	A1 - A20
B	Ceramic brackets with dove tail base design	20	B1 - B20
C	Ceramic brackets with mesh base design	20	C1 - C20
D	Ceramic brackets with dimple base design microcrystalline base design	20	D1 - D20
E	Ceramic brackets with dimple base design	20	E1 - E20
F	Stainless steel brackets with mesh base design	20	F1 - F20

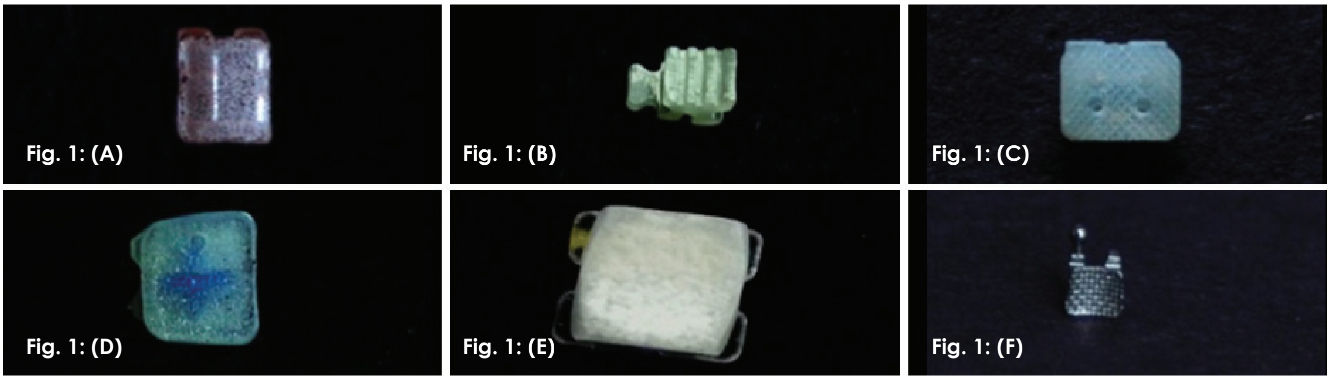


Figure 1: (A) Inspire Ice (Ormco Corporation, CA, Roth prescription, .022 slot) ceramic bracket with ball base design
(B) Illusion Plus (Ortho Organizer, CA, MBT prescription, .022 slot) ceramic bracket with dove tail base design
(C) InVu (TP Orthodontic, US, MBT prescription, .022 slot) ceramic bracket with mesh base design
(D) ClarityTM (3M Unitek, CA, MBT prescription, .022 slot) ceramic bracket with microcrystalline base design
(E) Allure (Dentsply GAC, NY, Roth prescription, .022 slot) ceramic bracket with dimple base design
(F) Elite Mini Twin Bracket (Ortho Organizer, CA, MBT prescription, .022 slot) stainless steel bracket with mesh pad base design.

All teeth were mounted individually in self cure-acrylic resin blocks of one inch size such that the long axis of the tooth was parallel to the long axis of the acrylic block and the crown of the tooth was exposed for bonding. The acrylic blocks with the teeth mounted were later stored in distilled water at room temperature before subjecting them to shear bond strength test. The samples were divided in six groups (A to F) of 20 samples each and each sample was labeled and numbered 1 to 20 (Table 1). After dividing all the samples in six groups each sample was subjected to bonding procedure and a bracket of that particular group was bonded on it (Figure. 1).

All samples were then subjected to thermocycling prior to bond strength testing. Thermocycling between 5-55°C was carried out for 500 times at 1 min/cycle.[6] The SBS was measured using Universal Testing Machine (Time Shijin Group, WDW-5). A mounting jig; that is a steel rod with flattened end, was attached to the crosshead of the universal testing machine and an occluso-gingival load was applied to the bracket parallel to the buccal surface of the tooth. The force required to shear off the bracket was recorded in Newton at a crosshead speed of 0.5 mm/minute.

After debonding, the teeth and brackets were examined under stereo-microscope of 10X magnification. Any adhesive remaining after bracket removal was assessed according to the adhesive remnant index (ARI) as modified from Bordeaux *et al*[7] (Table 2). The data obtained was tabulated and analyzed statistically.

Table 2: Types of bond failure

Type 1	Failure at the adhesive–bracket base interface. 90% or more of the bracket pad is exposed, and 10% or less of the bonded enamel is free of adhesive
Type 2	Combination failure at the adhesive–bracket base interface and the enamel-adhesive interface. Less than 90% but more than 10% of the bracket pad is exposed, or more than 10% but less than 90% of the bonded enamel surface is free of adhesive
Type 3	Failure at the enamel-adhesive interface. 10% or less of the bracket pad is exposed, and 90% or more of the bonded enamel is free of adhesive.
Type 4	Failure of the bracket itself. Fracture of the bracket during removal, left a portion of the bracket still bonded to the enamel surface
Type 5	Failure of the enamel itself. A portion of the enamel is removed along with the bracket base without loss of more than 10% of the adhesive from the bracket pad.

Table 3: Shear Bond Strength of experimental groups (in MPa)

Group	N	Mean	SD	SEM	95% Confidence Interval		Minimum	Maximum
					Minimum	Maximum		
A: Inspire Ice- Ormco (Ball base design)	20	21.80	1.29	0.29	21.20	22.41	19.96	23.99
B: Illusion Plus- Ortho Organizer (Dove-tail base design)	20	16.22	1.28	0.29	15.62	16.82	14.38	19.70
C: InVu- TP (Mesh base design)	20	16.33	1.41	0.32	15.68	16.99	14.03	18.91
D: Clarity- 3M Unitek (Microcrystalline base design)	20	20.84	1.72	0.39	20.03	21.64	18.35	24.17
E: Allure- Densply GAC (Dimple base design)	20	18.73	0.83	0.19	18.34	19.12	17.26	20.62
F: Elite- Ortho Organizer (Metal bracket- Mesh base design)	20	14.22	1.21	0.27	13.65	14.78	12.21	16.60

RESULT

Descriptive statistics of six experimental groups comparing Shear Bond Strength is given in Table 3. The study showed that Group A with ball base design had the highest bond strength of 21.80±1.29 MPa followed by Group D - microcrystalline base design having a bond strength of 20.84±1.72MPa, Group E - dimple base design with bond strength of 18.73±0.83MPa, Group C - mesh base design with a bond strength of 16.33±1.41 MPa, Group B - dove tail base design with a bond strength of 16.22±1.28 MPa and least for Group F - metal bracket with mesh base design with a bond strength of 14.22±1.21MPa.

All samples were also evaluated for the site of bond failure. In the brackets with ball base design; 80% of Type 3 bond failure was seen. In the brackets with dove tail base design 80% of Type 1 bond failure was seen. In the brackets with mesh base design; 75% of Type 1 bond failure was seen. In the brackets with microcrystalline base design 65% of Type 2 failure was seen. In the brackets with dimple base design 60% of Type 2 failure was seen. In the metal bracket with mesh base design 90% of Type 2 bond failure was seen (Table 4).

Graph 1: Mean and SD of Shear Bond Strength of test groups

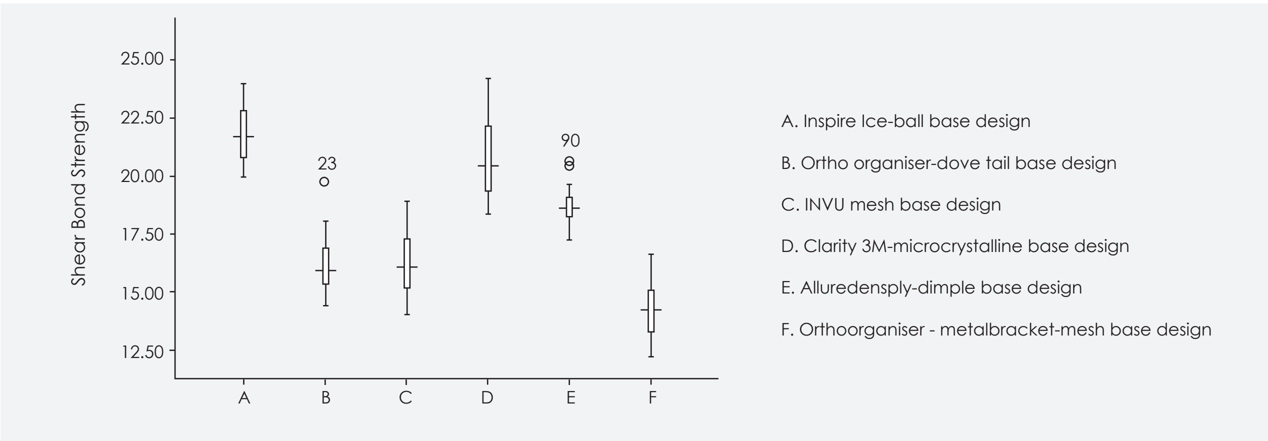
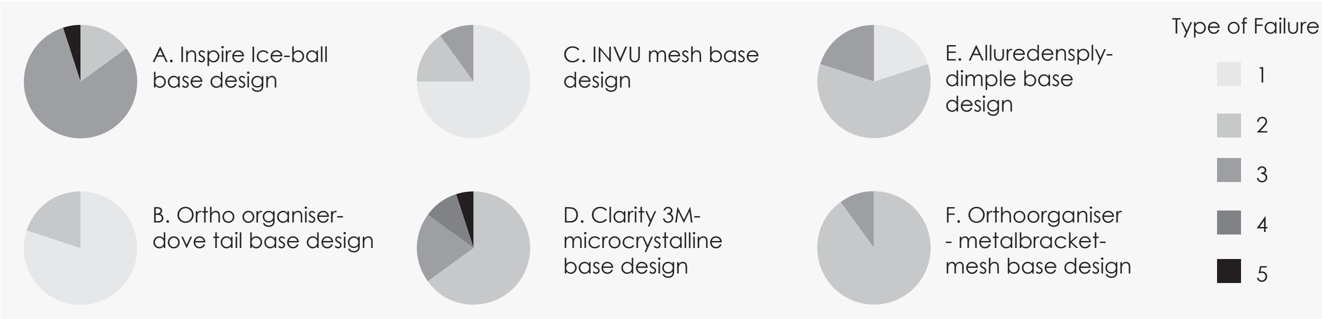


Table1: Distribution of Samples with Bond Failure

Type of bond failure		A	B	C	D	E	F
Type 1	Count	0	16	15	0	4	0
	% within groups	0%	80%	75%	0%	20%	0%
Type 2	Count	3	4	3	13	12	18
	% within groups	15%	20%	15%	65%	60%	90%
Type 3	Count	16	0	2	4	4	2
	% within groups	80%	0%	10%	20%	20%	10%
Type 4	Count	0	0	0	2	0	0
	% within groups	0%	0%	0%	10%	0%	0%
Type 5	Count	1	0	0	1	0	0
	% within groups	5%	0%	0%	5%	0%	0%



Graph 2: Type of Bond Failure

DISCUSSION

The possible reason for variation in results is variation in base designs of different ceramic brackets used in this study which differ from each other on the basis of the number of undercuts. On comparing mean SBS of different base designs it was observed that the statistically insignificant difference was seen between Group A and Group D. The probable reason for this insignificant difference could be because both the base designs offers sufficient undercuts for the mechanical retention. Similar insignificant difference was seen between Group B and Group C, this could be probably because of a very similar base design.

Group A offers maximum bond strength because the base geometry of this bracket is such that it has 50μm round mono-crystalline beads or balls completely distributed onto the base surface. These beads have undercuts for mechanical interlocking of adhesive resins. Group D also offers good bond strength but slightly less than Group A. The probable cause for good SBS is its microcrystalline base design, there are numerous glass particles (microcrystalline) distributed over the alumina base. This base geometry make the base surface rough which provides various undercuts for the mechanical retention.

Group E offers bond strength between Group A & D and Group B & C. The base geometry of this bracket is such that on a flat surface there are multiple pits so the undercuts created for mechanical interlocking is less than ball base design and microcrystalline base design, however it is better than the mesh base and dove tail base design. Among all ceramic brackets, dove tail base design offers the least bond strength. The base configuration of this bracket is such that there exist only three longitudinal groove at the base of the bracket hence offers little mechanical retention because of limited number of undercuts in the base design.

The result of our study also corresponds with the study by Kukiattrakoon *et al*.[8] In our study Inspire Ice-ball base design yielded the highest bond strength which is similar to the above mentioned study. The SBS of the metal bracket-mesh base design which is used as a control in our study also corresponds with the above mentioned study. However, in the above mentioned study there existed a significant difference between bond strength of Inspire Ice and Clarity bracket. All ceramic brackets used in the above mentioned study yielded bond strength greater than 19 MPa, however the ceramic brackets used in our study yielded bond strength below 19 MPa. The possible reasons for this variation are: absence of thermo-cycling and use of ceramic discs in place of extracted premolars in the above mentioned study.

In the present study, the stainless steel bracket showed least bond strength compared to ceramic brackets, which corresponds with the previous studies by Odegard,[9] Gwinnett,[10] Joseph *et al*,[11] Britton *et al*,[12] Flores *et al*,[13] Viazis *et al*,[14] and Spiro *et al*.[15] In all groups studied, the SBS was greater than 6-8 Mpa which is suggested by Reynolds[16] as optimum for orthodontic attachments.

All samples were also evaluated for the site of bond failure. Type 4 bond failure was seen in 10% of microcrystalline base design brackets. No other brackets showed such failure. This result corresponds with the study of Joseph and Rossouw,[11] who reported such failure in 6.66% of the ceramic brackets. From the clinical point of view it is critical because the fractured bracket could be ingested inadvertently.

Type 5 enamel fracture was seen in 5% with ball base design and microcrystalline base design, however no other bracket showed such result. It could be possibly because of the non-vitality of the tooth used in the study or might occur because of the high bond strength obtained with the rigid ceramic bracket. The safety margin of the stresses that could be withstood by the cohesive strength of the enamel was possibly reduced, which in turn could lead to an increase in enamel fracture.[11]

The present study evaluated the effect of bracket base design on shear bond strength; however an *in vitro* study cannot replicate the same environment as the oral cavity. The presence of saliva, proteins, minerals, differences in pH levels etc can affect the bond strength of ceramic brackets to enamel hence further study is recommended.

CONCLUSION

Following conclusions were drawn from the present study:

1. Ceramic brackets with ball base design yielded statistically highest shear bond strength among all groups followed by microcrystalline base, dimple base, mesh base and dove tail base design.
2. All ceramic brackets yielded bond strength higher than that of the metal bracket irrespective of their base designs.
3. The SBS of all groups exhibited higher values than the minimum orthodontic bracket bond strength range of 6-8 MPa.
4. Bracket base design is an important factor which can affect SBS. Base design with more number of mechanical undercuts offers better SBS.

OJN

REFERENCES

1. Birnie D. Orthodontic material update: Ceramic brackets. Br J Orthod. 1990; 17:71-5.
2. Bordeaux JM, Moore RN, Bagby MD. Comparative evaluation of ceramic bracket base designs. Am J Orthod Dentofac Orthop. 1994; 102:552–60.
3. Kao EC, Eliades T, Rezvan E, Johnston WM. Torsional bond strength and failure pattern of ceramic brackets bonded to composite resin laminate veneers. Eur J Orthod.1995; 17:533-40.
4. Samruajbenjakul B, Kukiattrakoon B. Shear bond strength of ceramic bracket with different base design to feldspathic porcelain. Angle Orthod. 2009; 79:571-76.
5. Sharma SK, Sayal, Rossouw PE, Kulkarni GV, Titley KC. The influence of orthodontic bracket base design on shear bond strength. Am J Orthod Dentofac Orthop. 2003; 124:74-82.
6. Turk SE, Turk T, Isci D, Ozkalayci N. Thermocycling effects on shear bond strength of a self-etching primer. Angle Orthod. 2006; 34:47-51.
7. Bordeaux JM, Moore RN, Bagby MD. Comparative evaluation of ceramic bracket base designs. Am J Orthod Dentofac Orthop. 1994; 102:552–60.
8. Kukiattrakoon B, Samraujbenjakul S. Shear bond strength of ceramic bracket with various base design bonded to aluminous and flouropatite ceramics. Eur J Orthod. 2010; 32:87-93.
9. Odegaard J, Segner D. Shear bond strength of metal brackets compared with a new ceramic bracket. Am J Orthod Dentofac Orthop. 1988; 94:201–6.
10. Gwinnett AJ. A comparison of shear bond strengths of metal and ceramic brackets. Am J Orthod Dentofac Orthop. 1988; 93:346–8.
11. Joseph VP, Rossouw PE. The shear bond strengths of stainless steel and ceramic brackets used with chemically and light-activated composite resins. Am J Orthod Dentofac Orthop. 1990; 97:121–5.
12. Britton JC, McInnes P, Weinberg R, Ledoux WR, Retief DH. Shear bond strength of ceramic orthodontic brackets to enamel. Am J Ortbod Dentofac Orthop. 1990; 98:348–53.
13. Flores DA, Caruso JM, Scott GE, Jeiroudi MT. The fracture strength of ceramic brackets: A comparative study. Angle Orthod. 1990; 60:269–70.
14. Viazis AD, Cavanaugh G, Bevis RR. Bond strength of ceramic brackets under shear stress: An in vitro report. Am J Orthod Dentofac Orthop. 1990; 98:214–21.
15. Spiro JC, Angelo AC, Gary SLN. Bond strength of ceramic brackets with various bonding systems. Angle Orthod. 1991; 60:269–76.
16. Reynolds IR. A review of direct orthodontic bonding. Br J Orthod. 1975; 2:171-8.
17. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod. 1984; 85:333-40.
18. Bishara SE, Laffoon JF. Effect of time on the shear bond strength of glass ionomer and composite orthodontic adhesives. Am J Orthod. 1999; 116:616-20.