http://jmscr.igmpublication.org/home/
ISSN (e)-2347-176x ISSN (p) 2455-0450
crossref DOI: https://dx.doi.org/10.18535/jmscr/v8i4.59

IGM Publication
Journal Of Medical Science And Clinical Research
An Official Publication Of IGM Publication

Evaluation of shear bond strength of ceramic brackets bonded to three different types of porcelain crowns: In vitro study

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Introduction

Smile aesthetics have influence on facial attractiveness and it strongly improves the personality and develops social interaction. So, every orthodontic patient has more concern to get the beautiful smiles at the end of orthodontic treatment but is also equally concerned with appearance while undergoing treatment. Many attempts have been made by manufacturers to meet this demand. This leads to innovative progress in orthodontic bracket systems, which resulted in the introduction of the smaller metal brackets, development of lingual or invisible aligners, making plastic brackets and at lastly translucent ceramic brackets. In mid 1980s ceramic orthodontic brackets were introduced in orthodontic world, as a more esthetically pleasing than the stainless steel brackets[1,2]. In adults, clinicians often bond orthodontic brackets to teeth that have different types of restorations such as porcelain crowns or laminates whereas adults prefer aesthetic looks even during the treatment, hence clinicians often bond ceramic brackets instead of metal brackets[3]. Porcelain surface do not bond readily with orthodontic brackets, the surface characteristics of porcelain are altered through certain approaches before bonding the brackets. Some of these are applying silane couplers, etching with hydrofluoric acid, or sandblasting the porcelain surface. Phosphoric acid solution is also used to enhance bond strength of the porcelain surface but it is not as efficient as hydrofluoric acid[4]. The bond failure at the bracket-adhesive interface is consider being safer than enamel- adhesive interface that results in increased incidence of enamel fractures. Artun J and Bergland S, 1984 modified the ARI which is one such index that evaluate the site of bond failure, that will be helpful in accessing the versatility of different ceramic brackets.[5]

Bond strengths between 6 and 8 MPa are clinically sufficient for successful bonding of brackets to enamel. Numerous studies have reported the effect of acid etching, etching duration, acid concentration, bond strength of different ceramics, but only few studies have attempted to correlate altered surface roughness after the surface treatment by etching, sand blasting & application of silane coupling agent. Hence, the present study has been advocated for evaluation of the shear bond strength of ceramic brackets bonded to three types of porcelain crowns and assessing their adhesive remnant index with surface roughness of crowns[6,7].

Materials and Methods

Subjects: This was a retrospective study in which total number of 90 porcelain crowns were used and calculated by using the PS Power and Sample Size Calculation software, version 3.0.43

Inclusion Criteria

1) All crowns were fabricated by the technician.
2) All crowns were fabricated using the same company materials.

Exclusion Criteria

1) Crowns with micro fractures were excluded.
2) Crowns with defective base materials were exclused

Three types of porcelain crowns were fabricated by a technician and allocated to the three groups as shown in FIG 1:

Group 1 consists of 30 porcelains fused to metal crowns.

Group 2 consists of 30 zirconia crowns.

Group 3 consists of 30 IPS e.max impress crowns.

Each group is divided into subgroups as follows

Group 1 was sub divided into subgroup A1, B1, C1 each consisting of 10 crowns.

Group2 was sub divided into subgroup A2, B2, C2 each consisting of 10 crowns.

Group 3 was sub divided into subgroup A3, B3, C3 each consisting of 10 crowns.

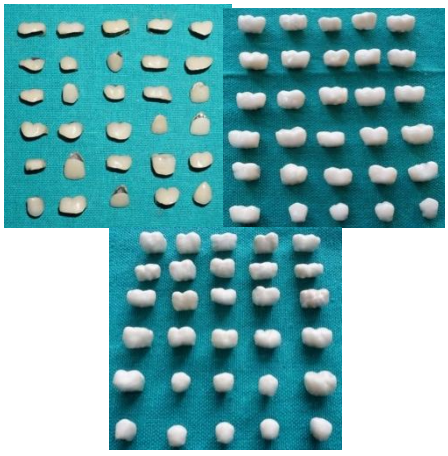

Fig 1

The 1st sub groups from three groups, A1, A2, A3 were surface treated by sand blasting for 5 seconds, etched with 9.6% of hydrofluoric acid etchant for 1 minute and rinsed with water/air combination for 30 seconds, dried and silane primer was applied and allowed to dry for 1 minute. [Fig 2]

Fig 2

The 2nd sub groups from three groups, B1, B2, B3 were surface treated by hydrofluoric acid and silane primer was applied. The 3rd sub groups from three groups, C1, C2, C3, were surface treated with hydrofluoric acid.

Surface roughness of each crown was determined by using profilometer [Talysurf CCI-2000] after the three different surface treatment methods. Ra (μm) is the average roughness value of a surface. Surface Measuring range was set as 3.5-4.5 mm in both the dimensions [length & width] [Fig 3]

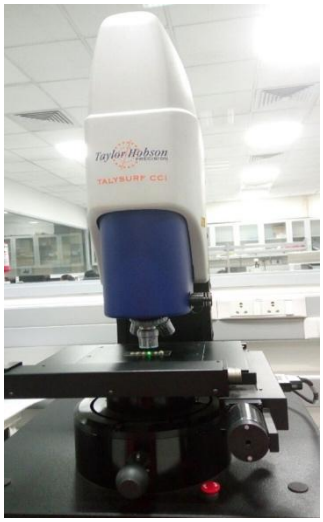

Fig 3

Using a syringe tip, the composite paste [Trans bond XT adhesive] was applied to the bracket.
The bracket was positioned on the crown and pressed lightly. Excess adhesive was removed with a sharp scaler. The specimens were cured with soft-start mode LED [Ivoclar Vivadent] for 40 seconds. [Fig 4]

Fig 4

These crowns were mounted on the different colored cold cure acrylic blocks for further procedures.

Fig 5

The bond strength of these brackets was tested using a universal testing machine (UTM) (Mecmesin 10-i)[8]. A cross head speed of 1mm/min was used to test the shear bond strength of orthodontic adhesive. The crowns were secured in a special jig attached to the base plate of a universal testing machine. The load was applied under the incisal wings of each bonded bracket and parallel to long axis of each mounted tooth. The load was applied till the bond failure occurred and the force required to debond the bracket was measured. The shear bond strength of each bracket was recorded in kilogram force which was then converted into megapascals (MPa), as it is a SI unit generally referred for bond strength. The SBS was then calculated. [Fig 6]

Fig 6

Once the debonding occurred, the brackets were then placed in the respective numbered glass bottles for identification[9]. These debonded brackets were examined under the stereomicroscope to assess the adhesive remaining on the bracket base at 10X multiplication. [Fig 7]

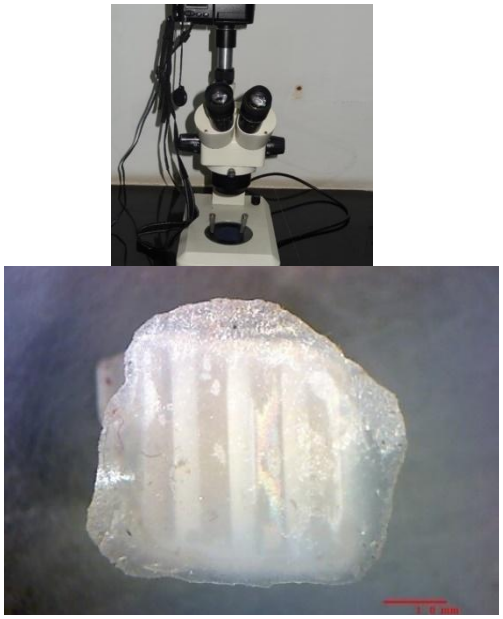

Fig 7

Any adhesive remnants were graded as per adhesive remnant index by Artunand Bergland.

0: All adhesive on bracket base

1: more than 50% of adhesive on bracket base

2: less than 50% of adhesive on bracket base

3: Entire adhesive left on the crown with a distinct impression of the bracket base.

Mean value was calculated from each sub groups & the lowest & highest values were determined.

Descriptive statistics including mean & standard deviation were calculated for each of the groups tested. One-way analysis of variance (ANOVA) and Tukey's Post Hoc analysis were used to compare the SBS, surface roughness & ARI index of the groups. Significance for all statistical tests was predetermined at $P<0.05$. All analyses were performed with the Statistical Package for Social Sciences version 17.0.0. The determined SBS, ARI values & surface roughness values of various groups namely Group 1, Group 2, Group 3 & sub groups namely subgroup A, subgroup B, subgroup C, were compared with each other using the above statistical analysis.

Results

After the surface treatment of 90 crowns the surface was examined under the profilometer for analyzing the surface roughness, later ceramic brackets were bonded & tested for shear bond strength using universal testing machine, SBS values were recorded at the point of debonding of brackets.

Later the deboned brackets were observed under stereoscopic microscope for scoring ARI values.

Shear Bond Strength

Group A1 had a shear bond strength of 7.170 ± 0.0823, while that of Group A2 and Group A3 was 8.850 ± 0.0707 and 8.680 ± 0.0632 respectively.

Group B1 had a shear bond strength of 6.930 ± 0.1059, Group B2 displayed a shear bond strength of 8.430 ± 0.0823, and that of Group B3 was 8.170 ± 0.0823.

Group C1 had a mean shear bond strength of 6.670 ± 0.1252, while in Group C2 it was 7.950 ± 0.1179, and in Group C3 it was 7.750 ± 0.0972.

Surface Roughness

Group A1 had a surface roughness of 0.1440 ± 0.00516, while that of Group A2 and Group A3 was 0.1410 ± 0.00568 and 0.1650 ± 0.00707 respectively.

Group B1 had a surface roughness of 0.1030 ± 0.00823, while that of Group B2 was 0.1090 ± 0.00738. Group B3 had mean surface roughness of 0.1460 ± 0.00516.

Group C1 had a surface roughness of 0.1260 ± 0.00516, while that of Group C2 was 0.1240 ± 0.00516, and that of Group C3 was 0.1320 ± 0.00632.

Adhesive Remnant Index

Group A1 had a mean ARI value of 2.40 ± 0.516, while that of Group A2 and Group A3 was 2.80 ± 0.422 each.

Group B1 had a mean ARI value of 1.40 ± 0.516, while that of Group B2 and Group B3 was 1.70 ± 0.483 and 1.60 ± 0.516 respectively.

Group C1 had a mean ARI of 0.40 ± 0.516, while in Group C2 and Group C3 it was 0.80 ± 0.422 each.

Discussion

The lowest bond strength result, 6.67 MPa, was obtained in PFM crown group (C1) which were surface treated with hydrofluoric acid, and the highest bond strength result, 8.850 MPa, was found in the zirconia crown group (A2) which were surface treated with sand blasting and etched with hydrofluoric acid and silane primer applied. Statistically significant differences were found in the bond strengths between all the groups & sub groups compared. Cohesive fractures was seen on the ceramic surface, if the bond strength results between the ceramic and the composite resin are greater than 13 MPa. The bond strength values in the three groups did not exceed this value. Similar results were observed in a study conducted by Raed Ajlouni[1] et al to evaluate the effects of a new self-etching primer/ adhesive used to enhance the

shear strength of orthodontic brackets bonded to porcelain surfaces[10,11].

The highest surface roughness, 0.1650 Ra was recorded in the IPS E.Max crown group (A3) which were surface treated with sand blasting for 5 seconds and etched with 9.6% of hydrofluoric acid etchant for 1 minute and silane primer applied. The lowest surface roughness, 0.1030 Ra was observed in the porcelain fused to metal crown group (B1) which were surface treated by etching with 9.6% of hydrofluoric acid etchant for 1 minute & dried and silane primer applied. Statistically significant differences were found in the surface roughness between all the groups & sub groups compared with tukey's post hoc analysi[12,13].

A Study was undertaken by Ravikumar Ramakrishnaiah[2] et al to evaluate the effect of hydrofluoric acid etching duration on the surface characteristics of five silica-based glass ceramics showed a similar result[14,15,16].

No statistically significant difference was observed between the ARI scores for the three types of crowns ($P > 0.05$). Though there were no significant differences between the groups, a significant difference can be observed between sub groups A, B & C.

Conclusions

- Ideal bond strength for bonding ceramic brackets to PFM crowns was found in sub group C1 which were surface treated with hydrofluoric acid. The ideal bond strength for zirconia and IPS E.Max were found in crowns surface treated by etching with hydrofluoric acid and silane primer applied.
- Maximum surface roughness & damage to the crown was observed in sub group A where crowns were surface treated with sand blasting, etched with hydrofluoric acid and silane primer applied.
- There were no significant differences in ARI values between the different sub groups, but significant difference was observed in the different crown materials.

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