Bond strength of metal orthodontic brackets to all ceramic crowns.

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SUMMARY

Introduction

The demand for orthodontic treatment in adult patients has increased considerably, in many cases requiring orthodontists to place attachments onto ceramic restorations.

Aim

This study evaluated, in-vitro, the shear bond strength (SBS) of metal orthodontic brackets to all- ceramic crowns.

Method

40 IPS eMax crowns and 40 porcelain-veneered zirconia crowns were manufactured. Group 1: n=20 crowns and Group 2: n=20 crowns were thermocycled. Groups 3 and 4: n=40 crowns, were not exposed to thermal changes. The facial surfaces of all crowns (n=80) were etched by the application of 35 % ortho-phosphoric acid liquid for 2 minutes, followed by the application of a thin layer of a ceramic primer. After bonding, all samples were stored in distilled water for 24 hours before debonding. Data were analysed using side by side Box-and-Whisker plots, the Kruskal-Wallis test ($p < 0.05$) and the Bonferroni Test.

Results

Group 3: mean SBS 5.1 MPa (45.5 Newtons) to 5.8 MPa (51.9 Newtons). Group 4: mean SBS 6.4 MPa (57.3 Newtons) to 8.1 MPa (72.7 Newtons). ARI values further highlighted the negative influence of thermocycling.

Conclusion

There was no significant difference in the shear bond strengths of RelyXTM Unicem 2 and TransbondTM XT bonded to all-ceramic crowns.

INTRODUCTION

There has been an increasing interest and demand for the use of all-ceramic materials to restore severely damaged teeth or to replace lost teeth, particularly in adult patients. In the anterior region, the most commonly fabricated silica based ceramic crown is the IPS eMax crown and the most commonly fabricated high strength ceramic crown is the feldspathic porcelain veneered zirconia based crown. Although the veneered porcelain reduces the flexural strength of the zirconia based ceramic, translucency is greatly improved making it more aesthetically pleasing in the anterior regions.[1]

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ACRONYMS

ARI : Adhesive Remnant Index

HFA : Hydrofluoric acid

SBS : shear bond strength

The demand for orthodontic treatment in adult patients has been increased considerably, together with an increase in patients' knowledge and the changes in modern lifestyle. As a result, orthodontists are frequently required to attach orthodontic attachments or fixed retainers to teeth which may have been previously restored with ceramic restorations such as crowns or veneers.

Ceramic is an inert material and does not adhere chemically to any of the currently available bonding resins. Therefore, in orthodontics, ceramic surface preparation is an essential step prior to bonding. However, mechanical alteration (sandblasting and using diamond burs) to roughen the surface of porcelain can cause irreversible damage and compromise the integrity of the porcelain crown.[2] Anecdotal evidence suggests that bonding orthodontic brackets with silane coupling agents and phosphoric acid or hydrofluoric acid creates a bond of sufficient strength for orthodontic treatment.[2-,6]

The overall time required to place an appliance is an important factor in the cost of the treatment.[2] Newer, self-adhesive cements have the potential to further simplify the bonding process.[7] Reducing the steps during the bonding process will also reduce the risks of saliva contamination and the effects of humidity, both of which could have an adverse effect on the bond strength of the resin cement.

On the one hand, optimum bond strength is required for minimizing bond failures during the treatment phase, and on the other hand, the porcelain on the restored tooth should ideally return to its initial state of appearance, without any damage to its surface after the brackets are removed.[8]

Although there are innumerable protocols for bonding orthodontic brackets to porcelain, there is still no scientific consensus about which of the techniques would be the ideal standard protocol for the purpose of overcoming the two contrasting requirements mentioned above.[9]

Hence, the purpose of the present study was to test and compare the shear bond strength and the resultant failure pattern of two types of resin adhesive cements (RelyXTM Unicem 2, a self-adhesive resin cement and TransbondTM XT, a two step bonding resin cement) to etched and silane treated all- ceramic crowns. Additionally, a further aim of this study was to examine an alternative to etching with hydrofluoric acid, which is noxious and harmful. Instead, etching with 35% ortho-phosphoric acid and silane coupling application as pre-treatment preparation of the all ceramic crown surfaces before bonding was investigated. Furthermore, the study tested the effect of thermocycling, included to simulate the oral environment on the shear bond strengths. Many studies have not considered this aspect.

AIM

This study was conducted in-vitro to evaluate the shear bond strength (SBS) and the resultant failure pattern after debonding, of metal orthodontic brackets bonded with TransbondTM XT and RelyXTM Unicem 2 self-adhesive resin cement to pre-treated (35% ortho-phosphoric acid and silane coupling agent application) IPS eMax and porcelain veneered zirconia crowns.

MATERIALS AND METHODOLOGY

A typodont maxillary lateral incisor was used and prepared in a conventional manner to receive a full ceramic crown. A CAD (computer aided design)/ CAM (computer aided manufacturing) machine was used to scan the prepared tooth and to manufacture 40 IPS eMax crowns. A skilled technician prepared an additional 40 porcelain veneered zirconia crowns. Half the number of IPS eMax crown specimens (n=20) and half the number of porcelain veneered zirconia crown specimens (n=20) were thermocycled (i.e. to mimic thermal changes which occur in the mouth), from 5° to 55° for 500 cycles as recommended by the International Organization for Standardization (ISO 6872, 2008) (Figure 1).

Figure 1: Thermocycling apparatus used.

The remaining 20 IPS eMax crown specimens and 20 porcelain veneered zirconia crown specimens remained pristine and unexposed to thermal changes. The facial surfaces of all the thermocycled and non-thermocycled crown specimens were then etched. Etching of all the ceramic bonding surfaces was performed by the application of 35 per cent ortho-phosphoric acid liquid for two minutes, followed by a thin layer of a ceramic primer. The crowns were separated into four groups, Groups 1 and 2 each comprising 10 thermocycled etched and silane treated IPS eMax and 10 thermocycled and etched and silane treated porcelain veneered zirconia crown specimens, Groups 3 and 4 comprising the non-thermocycled combinations. A lateral incisor metal bracket with a bracket base area of $9mm^2$ (as confirmed by the manufacturer) was bonded to each of the etched and silane treated ceramic crown specimens, the cement and technique varying with each group as follows : Group 1: RelyX™ Unicem 2 self-adhesive resin cement. Group 2. Transbond™ XT light cure adhesive primer was first applied onto the bonding surface of the crowns and then Transbond™ XT adhesive resin was used. Group 3: RelyX™ Unicem 2 self-adhesive resin cement. Group 4: Transbond™ XT light cure adhesive primer was first applied onto the bonding surface of the crowns and then Transbond™ XT adhesive resin cement was used. (Figure 2).

After bonding all samples were stored in distilled water for 24 hours before being submitted to the shear bond strength test (Figure 3). Debonding forces in Newtons (N) were determined by using a shear testing machine and the values converted into Mega Pascals (MPa).

After debonding, the surfaces of crown and resin were examined to determine the mean Adhesive Remnant Index (ARI) values and the Porcelain Fracture Index.[8]

Figure 2: Crown embedded and bonded with a metal bracket. Labelled according to particular groups.

Figure 3: The knife-edged rod of the shearing machine positioned at the bracket-ceramic interface.

RESULTS

Table 1 shows the SBS values in Newtons (N) and Mega Pascals (MPa) of the different resin/crown combinations of Groups 3 and 4.

Figure 4 shows the side by side Box-and-Whisker plots of the shear bond strengths demonstrating wide and overlapping dispersions of the resin/crown combinations which consequently lessens the probability of significant differences occurring between the data of the resin/crown combinations in all four groups.

Table 1: Groups 3 and 4: SBS values of different resin/crown combinations of the non -thermocycled samples. (RXU- E = RelyX™ Unicem 2- E max ; RXU Z = RelyX™ Unicem - Zirconium ; TbXT-E= Transbond™ XT -Emax ; TbXT-Z= Transbond™ XT- Zirconium)		
Combinations	**SBS N**	**SBS MPa**
RXU-E	45.5	5.1
RXU-Z	51.9	5.8
TbXT-E	72.7	8.1
TbXT-Z	57.3	6.4

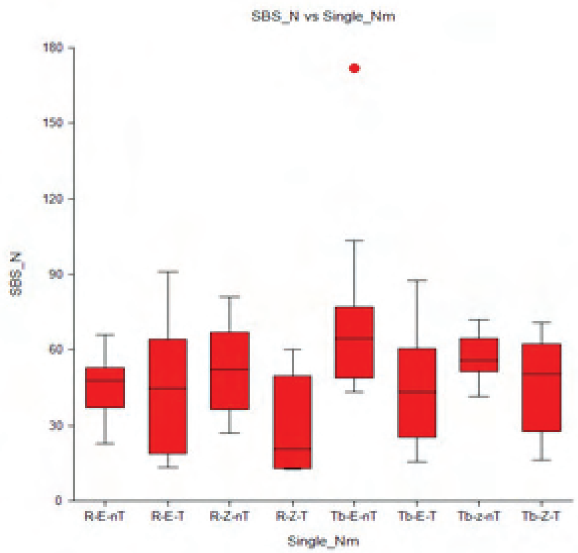

Figure 4: Side by side Box-and-Whisker Plots of the SBS (N) values for the eight adhesive/crown combinations (Re = RelyX™ Unicem 2 ; E = E max ; T = Thermocycled ; nT = not thermocycled ; Tb= Transbond™ XT ; Z= zirconium)

Table 2: Groups 1 and 2: SBS of different resin/crown combinations of the thermocycled samples. (RXU- E = RelyX™ Unicem 2- E max ; RXU Z = RelyX™ Unicem - Zirconium; TbXT-E= Transbond™ XT - Emax ; TbXT-Z= Transbond™ XT - Zirconium)		
Combinations	**SBS N**	**SBS MPa**
RXU-E	44.5	4.9
RXU-Z	29.1	3.2
TbXT-E	46.1	5.1
TbXT-Z	45.8	5.1

According to the Kruskal-Wallis test ($p < 0.05$), and the Bonferroni Test the data of the non-thermocycled resin/crown combinations did not differ significantly.

Table 2 shows the SBS values in Newtons (N) and Mega Pascals (MPa) of the different resin/crown combinations of Groups 1 and 2.

The results of the thermocycled groups (Group 1 and Group 2) show the TransbondTM XT/non-thermocycled IPS eMax crown combination yielded the highest overall mean shear bond strength of 8.1 MPa (72.7 Newtons) (Table 1) but dropped to a mean shear bond strength of 5.1 MPa (46.1 Newtons) (36.4% drop in shear bond strength) when the crowns had been thermocycled prior to bonding (Table 2). The TransbondTM XT/non-thermocycled porcelain veneered zirconia crown combination yielded the second highest overall mean shear bond strength of 6.4 MPa (57.3 Newtons), which also dropped, to a mean shear bond strength of 5.1 MPa (45.8 Newtons) (19.3% drop in shear bond strength) when the thermocycled crowns were used. The RelyXTM Unicem 2/non-thermocycled porcelain veneered zirconia crown combination yielded the third highest overall mean shear bond strength of 5.8 MPa (51.9 Newtons), The adhesive strength recorded on the thermocycled crowns was a significant 43.8% lower at a mean shear bond strength of 3.2 MPa (29.1 Newtons). Lastly, the RelyXTM Unicem 2/non-thermocycled IPS eMax crown combination yielded the fourth highest mean shear bond strength of 5.1MPa (45.5 Newtons) but dropped to a mean shear bond strength of 4.9 MPa (44.5 Newtons) (a drop in shear bond strength of only 3%) when the crowns had been thermocycled prior to bonding.

The non-thermocycled resin/crown combinations showed mean ARI values of between 1.3 and 2.1 indicating cohesive fractures within the composite resin and efficient bonding of the adhesive material to the porcelain surface. However, all the thermocycled resin/crown combinations showed mean ARI values of between 0 and 0.8, indicating a bond failure between adhesive and porcelain and highlighting the negative influence of thermocycling on the bond strength of both adhesive resin cements. No cohesive fractures of the porcelain crowns were noted.

DISCUSSION

Optimal bracket adhesion to the bonding surface of porcelain crowns is always of concern to orthodontists because the forces applied during treatment should not result in bond failure. Glazed porcelain is not an appropriate surface for resin penetration and orthodontic bonding.[10] Recommended surface treatment methods can be time consuming or even harmful to soft tissues. Hydrofluoric acid (HFA) etching is an effective surface treatment for porcelain-composite bonding.[11] However, the risk of soft tissue burns and the toxic effects of HFA requires extreme care during intraoral application, causing many orthodontists to be hesitant in its use.[5,12] Etching of porcelain surfaces with phosphoric acid alone does not provide shear bond strength sufficient to resist the forces applied during orthodontic treatment.[13] Anecdotal evidence suggests that brackets bonded with silane coupling agents and phosphoric acid or hydrofluoric acid will have adequate bond strength for orthodontic treatment.[2,-6] Phosphoric acid does not etch porcelain, and it does not produce physical or topographical changes in the porcelain surface. Instead, phosphoric acid has the effect of neutralising the alkalinity of the adsorbed water layer, which is present on all porcelain restorations in the oral cavity. This enhances the chemical activity of the silane coupling agents which are subsequently applied.[14-16] Silane coupling agents have been reported to enhance bond strength to porcelain surfaces.[11,17-21] The silane reacts with the silica within the porcelain and the organic groups of the bonding resin, thus forming a bridge between the two materials.[20]

There are a few scientifically-based recommendations in the literature for minimum orthodontic bracket shear bond strength. A tensile force of 60kg/cm^2 to 80kg/cm^2 has been recommended, while Newman[20] stated that 14kg/cm^2 was the maximum that should be applied by an orthodontic appliance. Whitlock et al.,[22] suggested that 6-8 MPa was adequate for orthodontic attachments and this was used as the reference value in the present study.

The Adhesive Remnant Index and the Porcelain Fracture Index were also examined to establish which regime produced adequate strength for orthodontic bracket attachment to all-ceramic crowns, with the least porcelain surface damage following bracket removal. As this appears to be the first shear bond strength study on IPS eMax and porcelain-veneered zirconia crowns conditioned with 35% phosphoric acid and a silane coupling agent, there are no published values with which to compare. Shear bond strength values were compared with results from bonding orthodontic brackets to ceramic crowns conditioned with Hydrofluoric acid (HFA) and a silane coupling agent. Jivanescu and Bratu[23] compared the performance of RelyXTM Unicem self-adhesive resin with that of a light cured bonding system on porcelain-fused to metal crowns which were conditioned with 10% HFA, a primer and an adhesive. No statistically significant differences were found. They concluded that both materials may be recommended for bonding orthodontic brackets to ceramic surfaces. In the current study, the shear bond strength of the RelyXTM Unicem 2 dual-cured, self adhesive resin/ IPS eMax crown combination was 5.1 MPa and 5.8 MPa for the RelyXTM Unicem 2 dual-cured, self-adhesive resin/ porcelain veneered zirconia crown combination. In Group 3 and Group 4, no statistically significant differences were found in the shear bond strengths of any of the combinations. This is in agreement with a study by Bilgic et al.[24,25] who had treated the porcelain surfaces with 9.6% HFA and a silane primer. However, Turk et al.[26] reported that lithium disilicate had a higher shear bond strength (SBS) than feldspathic porcelain restorations. Moreover, Abu Alhaija and Al-Wahadani[6] observed significant differences between feldspathic and lithium disilicate ceramic restorations (IPS Empress 2 - an earlier version of IPS eMax crown), with higher mean shear bond strength (SBS) reported for the feldspathic porcelain group. This may also be due to the structural differences between IPS Empress 2 crown and the IPS eMax crown. A study which used a 9.6% HFA etch and silane primer found the IPS eMax crowns to have the greatest shear bond strength.[27] The ceramo-metal and ceramo-zirconia crowns had comparable shear bond strengths. This may be due to the differences in the processing methods and the molecular structure of the all-ceramic restorations. In the current study, a statistically significant difference was found between the shear bond strengths recorded in the non-thermocycled and thermocycled groups. The adverse influence of thermocycling can be seen on the measured shear bond strength values.

CONCLUSION

Within the limitations of this study, it can be concluded that:

1. There was no significant difference in the shear bond strengths of metal orthodontic brackets bonded with RelyXTM Unicem 2 self-adhesive resin cement and metal orthodontic brackets bonded with TransbondTM XT adhesive resin cement to IPS eMax and porcelain-veneered zirconia crowns which were conditioned with 35 % phosphoric acid and a silane coupling agent.
2. Conditioning the porcelain surface with 35% phosphoric acid and a silane coupling agent (which is safer to use than Hydrofluoric acid) provides a substrate which enables the satisfactory bonding of metal orthodontic brackets to all ceramic crowns, and should make it simpler for clinicians to remove the remaining adhesive from the porcelain surface after debonding.

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