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Evaluation of Fracture Strength of Cemented Monolithic Zirconium Crown Using Different Types of Luting Agents: *In vitro* Comparative Study

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ABSTRACT

Background/purpose: *The longevity of fixed partial denture depends on the type of luting cement used with tooth preparation. This study was planned with an aim to evaluate fracture strength of monolithic zirconium crown by using different types of luting agents.* ***Materials and methods:*** *32 sound maxillary first premolar teeth freshly extracted for orthodontic purposes were selected and collected to be used in this in vitro study. Teeth were divided into four groups: Group 1, control group (no cement), Group 2, GIC conventional (SDI), Group 3, TheraCem self-adhesive resin cement, Group 4, Duo-link universal adhesive. Standardized preparation for full contour zirconia crown restorations was carried out finishing lines depth 1.0 mm, total axial tapered of 6 degrees and axial height 4 mm. The teeth were then scanned directly. Full contour zirconia crown restorations were then fabricated. Deep chamfer finishing line was used in this study.* ***Results:*** *The study revealed that the least fracture resistance of monolithic zirconium crown Group 1 (2036.25 N), Group 2 (2272.50 N), Group 3 (2642.50 N), Group 4 (3318.75 N) respectively. Comparison of significance among the different groups using one-way ANOVA test showed statistically highly significant differences (p<0.01). Further, comparison between each group using Student's t-test revealed the difference between G1 and G2 was statically non-significant while the difference between G1 and G3 and between G3 and G4 was statically significant. Furthermore, the difference between G1 and G4, also between G2 and G4 was highly significant. There was non-significance between GIC group and TheraCem® group, p>0.05.* ***Conclusion:*** *Duo-Link Universal™ adhesive was found to be more resistant to fracture strength followed by TheraCem® self-adhesive resin cement than GIC conventional (SDI) which is the least resistant luting agent.*

Keywords: Adhesive cement, Resin cements, Zirconium oxide, Bisphenol A-Glycidyl Methacrylate

INTRODUCTION

The name "Zirconium" comes from Arabic word "Zargon" which means "golden in color" which in turn comes from the two Persian words, Zar (gold) and Gon (color) [1,2]. Dental ceramics present numerous favorable characteristics including biocompatibility and excellent potential to simulate the optical characteristics of natural teeth [3].

Full contour implies restorations in their final shape, with great occlusal detail; high translucency allows the material to blend naturally with neighboring teeth [4]. Monolithic zirconia crowns possess sufficient fracture resistance for dental crown restorations due to high strength of the material. This resistance is attributable to stress-induced transformation toughing in yttria stabilized zirconia [5]. Fractures of zirconia are not a common problem, although ceramics, including zirconia, are referred to as brittle materials [6].

Monoclinic ZrO_2 (m-ZrO_2) exists at temperatures lower than 1170°C. Tetragonal ZrO_2 (t-ZrO_2) exists between 1170°C and 2370°C. When temperatures are higher than 2370°C, the phase transition from t-ZrO_2 to cubic ZrO_2 (c-ZrO_2) occurs [7]. The concentration of the stabilizer plays a decisive role in the performance of this material under fatigue and the addition of 2-3 mol% Y_2O_3 results in partially stabilized tetragonal zirconia, which is the most attractive composition for transformation toughness [8].

This mechanism is primarily responsible for the superior mechanical properties of zirconia, since it may undergo phase transformation from tetragonal to monoclinic under localized stress, with a subsequent increase of about 4% to 5% of local volume, inhibiting crack propagation. However, due to its metastable nature, zirconia-based materials are susceptible to unfavorable phase transformation at room temperature, and this phenomenon is known as "low temperature degradation" (LTD) [9]. Aging occurs through an uncontrolled slow transformation of superficial grains from tetragonal to monoclinic phase in contact with water. This creates surface roughness and formation of microcracks, creating possibilities for water penetration causing further phase transformation and consequent loss of mechanical strength [10].

Dental cements are used as luting agents and restorative materials in the oral cavity. The most obvious use of dental cements is for permanently retaining metallic and non-metallic inlays, crowns, and bridges to tooth structure. Cements used in this manner are called luting agents because they lute, or adhere, one surface to another. Other uses of dental cements include bonding of orthodontic appliances to the teeth and cementing pins and posts to retain restorations [11].

The use of restorative cements is restricted only to low stress bearing areas since they have low strength compared to resin-based composites and amalgam. Dental cements can also be used as protecting materials after the cavity preparation to protect the pulp against further trauma, like thermal and chemical-insulating bases under metallic restorations and others like composites restorations and pulp-capping agent and cavity liners. Some fluoride-containing cements can be used as fissure sealants, root canal sealants, and core build-up for restoration of broken-down teeth [12].

MATERIALS AND METHODS

Cements

Three different types of cements were used; glass-ionomer cement (GIC; Fuji I, GC, Tokyo, Japan), TheraCem® (BISCO, Inc. USA), Duo-Link Universal™ (BISCO, Inc. USA).

Thirty-two sound human maxillary first premolar teeth of comparable size and shape extracted for orthodontic purposes from patients with age range 18-25 years were selected to be used in this *in vitro* study. Teeth were cleaned carefully for any calculus and soft tissue deposits with air scalar and polished with pumice paste [13,14]. The selected teeth were free from caries.

Tooth Preparation

A standardized full crown preparation for each tooth sample was performed using high speed hand piece, with water coolant, that adapted to the horizontal arm of the modified dental surveyor. The acrylic specimen that hold the tooth was adapted and secured to the movable table of the surveyor in such a way, so that the long axis of each clinical crown kept parallel to that of the bur all the way during tooth preparation procedure.

Each tooth sample was then, prepared to receive zirconium crown restoration with the following preparation features: anatomical occlusal reduction, 1 mm deep chamfer finishing line all around the tooth with total circumferential axial reduction about (1-1.5 mm), 4 mm axial wall length and total axial tapered 6° [15,16]. Two diamond taper fissure burs of similar shape, size and diameter with round end were used in this study to get a standardized axial preparation, one of them with coarse diamond particles was used for axial surface reduction (No. 6856, Komet, Germany) while the other were with fine diamond particles for smoothing and finishing (No. 8856, Komet, Germany).

Fabrication of Crowns

A three-dimensional digital image for each tooth sample was taken by CEREC Apollo DI intra-oral scanner (Sirona Dental Systems, Bensheim, Germany)

MODEL Phase

The next step was designing of the crown in "MODEL" phase, which determined the margin of the preparation that was automatically detected by the system. The undercut was checked, the path of insertion was determined and the position of tooth in the arch was also determined.

Sample Grouping

According to the type of luting agent used during cementation of the crown to the prepared tooth the specimens divided into four groups of (n=8) for each:

Group 1: control group; no cement was used for this group.

Group 2: glass-ionomer cement (GIC) was used as luting cement.

Group 3: TheraCem® self-adhesive resin cement was used.

Group 4: Duo-Link Universal™ adhesive resin cement was used.

Specimen Holding and Cementing Device

A custom made holding device was especially fabricated to be used as a screw that secured the zirconia crown on the natural tooth sample during marginal checking and cementation procedure to maintain standardized seating forces. The device was designed to have a load sensor attached to it [17]. Furthermore, a modification was done on this device so that it will hold the crown parallel to the path of insertion of the prepare tooth during crown seating procedure by attaching the vertical arm of the device to the vertical arm of the surveyor. In order to apply the seating force more evenly and parallel to the path of insertion, a square custom-made mold of 8 mm × 4 mm with central round hole about 1 mm larger from the crown circumferential was attach to the tighten screw end of the device.

Prior to cementation of the zirconium crown, the hold was filled with special type of silicon to cover 3 mm of occlusal surface of each cemented crown. Each crown was seated on the tooth sample with a standard load of 5 Kg (≅50 N) [18,19].

Cementation of Crown Restoration

Prior the cementation procedure for all groups, the teeth was cleaned by alcohol to remove debris in order to standardize the mount of luting agent during cementation procedure. For all groups of zirconia crown, the teeth were cleaned by alcohol, the luting agent were injected inside the inner surface of the crown until it complete filled.

Each crown was then seated on it to fit tooth with finger pressure initially then a static load of 5 Kg was applied for 6 minutes according to the manufacturer's instructions using the specimen holding device. Excess material was removed with a fine micro brush before complete polymerization. Each cemented specimen was kept for one hour to bench set. All specimens were then stored in distilled water at room temperature and then tested after one week after cementation [20].

Testing Procedure

In order to be suitable with sample size of this study, two modifications have been done on Instron test machine, one involved the upper jaw while the other involved the lower jaw (Figure 1).

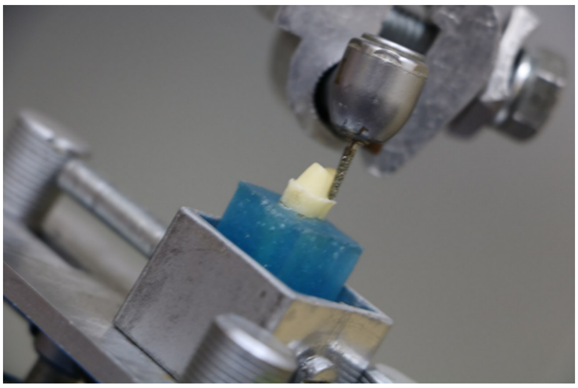

Figure 1 Instron test machine with modifications for testing

For upper jaw, Instron testing machine was mounted with a movable rod with semispherical head of 5 mm diameter attached to the upper jaw through the loading piston, while for the lower jaw, specially designed sample holding device was mounted to the lower jaw of the testing machine to securely hold the specimen.

After one week of storage in distilled water, the specimen was secure on their position on Instron testing machine, the occlusal surface of the crown was covered by 1 mm thick rubber sheet, the loading force was then applied at the center of occlusal surface along the long axis of cemented crowns with a crosshead speed of 0.5 mm/min until fracture occurred [21-23].

The load deflection curves were recorded with computer software and the fracture load data were automatically recorded in Newton using Vista software figure.

RESULTS AND DISCUSSION

A total of 32 measurements of fracture strength from four groups were recorded for three different types of luting agents. The means and standard deviations of fracture strength with minimum and maximum values which were calculated for each group are listed in Tables 1-3.

Table 1 Descriptive statistics of fracture strength of the CAD/CAM (INCORIS TZI C) by using different types of cements (Newton)

Groups	Number	Mean	SD	Min	Max
G1	8	2036.25	326.49	1550	2590
G2	8	2272.5	454.27	1710	2870
G3	8	2642.5	404.78	2120	3250
G4	8	3318.75	574.74	2700	4190
Total	32	2567.5	651.65	1550	4190
SD: Standard Deviation; Min: Minimum; Max: Maximum					

Table 1 shows that the lowest mean of fracture strength was recorded in Group 1 (control group) (2036.25 N) and then the crown that cemented with GIC luting agent (2272.50 N), also the mean was recorded in group 3 (2642.50 N) which represent crown that cemented with TheraCem® (BISCO, Inc. USA). While the highest mean group was recorded in group 4 (3318.75 N) which represent crown that cemented with (Duo-Link Universal™) this clearly shown.

To see whether the difference in the mean value for all groups was statistically significant or not, one-way (ANOVA) test was applied (Table 2).

Table 2 Inferential statistics data

Loads	Sum of squares	df	Mean square	F-value	p-value
Between groups	7514025	3	2504675.00	12.413	0.00
Within groups	5649975	28	201784.82		
Total	13164000	31	-	-	-

This table shows that the difference in fracture strength between three different groups were statistically highly significant, in order the localized the source of difference further statistical analysis of the result was than Student's t-test (Table 3).

Table 3 Comparison of the groups

Groups compared	t-test	P value
G1 vs. G2	-1.194	0.252†
G1 vs. G3	-3.297	0.005*
G1 vs. G4	-5.488	0.00***
G2 vs. G3	-1.72	0.107†
G2 vs. G4	-4.039	0.001***
G3 vs. G4	-2.721	0.017*
*P ≤ 0.05 Significant; ***P ≤ 0.001 Highly Significant; †Non-significant		

Table 3 shows that the difference between G1and G2 was statically non-significant while the difference between G1 and G3 and also between G3 and G4 was statically significant. Furthermore, the difference between G1 and G4, also between G2 and G4 was highly significant. There is no significant difference between GIC group and TheraCem® group.

CONCLUSION

From the current study, it can be concluded that Duo-Link Universal™ adhesive was found to be more resistant to fracture strength followed by TheraCem® self-adhesive resin cement than GIC conventional (SDI) which is the least resistant luting agent.

DECLARATIONS

Conflict of Interest

The authors and planners have disclosed no potential conflicts of interest, financial or otherwise.

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