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The Effect of Die Spacer Thickness on Retentive Strength of all Zirconium Crowns (An *In vitro* Study)

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ABSTRACT

Aim: *The purpose of this study was to evaluate the effect of different die-spacer thicknesses on the retentive strength of all zirconium crowns using self-adhesive resin cement (Relyx Unicem).* ***Materials and method:*** *A total of 24 freshly extracted sound human maxillary first premolar teeth were mounted and then received a standardized preparation for full contour zirconia crown restorations with a deep chamfer finishing line, planner occlusal reduction, 6° overall taper. The teeth were scanned directly using Sirona Omnicam digital intra-oral scanner. Preparations surface areas were measured using Auto CAD architecture software. Teeth were then randomly assigned into 3 main groups according to the die spacer thickness selected during the designing phase by inLab SW 16.1 designing program (n=8): Group A: 80 µm; Group B: 100 µm and Group C: 120 µm. Monolithic zirconia crowns were constructed using Sirona In-Lab MC X5 milling unit. Each group was cemented with Relyx Unicem self-adhesive luting cement.* ***Statistical analyses:*** *The data were statistically analyzed using 1-way ANOVA and Post-hoc Bonferroni test at 0.05 level of significance.* ***Results:*** *The statistical analysis showed that die spacer thickness had a significant effect on the crown retentive stress and the highest mean of retentive stresses was recorded for Group A (7.4 ± 0.7 SD) while Group C recorded the lowest mean of retentive stresses (5.5 ± 0.8 SD). In addition, the predominant mode of failure was type 3 (cement principally on ceramic).* ***Conclusion:*** *Within the limitations of this study, the use of 80 µm spacer thickness resulted in significally higher retention values than 100 µm and 120 µm spacer. In contrast, there was no significant difference in retention between 100 µm and 120 µm.*

Keywords: Die spacer, Retention, CAD CAM, Zirconia

INTRODUCTION

Over the last few years, there has been a tremendous shift towards high-strength, all-ceramic crowns; particularly those produced from zirconium oxide (ZrO_2) ceramics, because of their excellent biocompatibility, esthetic and mechanical properties [1]. A frequent cause of crowns and bridges failure was reported as a loss of retention [2]. Only dental caries and porcelain failure cause more failure of fixed dental prostheses than does the loss of retention. Retention form could be defined as the quality of a preparation that keeps the restoration from being dislodged by such forces parallel to its insertion pathway. The retention of a single crown might be depended on several factors such as the tooth preparation geometry, amount of the dislodging forces, roughness of the internal surface of the restoration, crown materials being cemented, film thickness and other properties of the luting cement [3]. Furthermore, restoration fitness plays a significant role in the retention of a crown restoration [4]. Many researchers have agreed that die spacing during crown fabrication would improve its fitness during cementation. However, it might also improve the retention of the cemented crown [5]. In the past, researchers theorized that better retention could be obtained with a frictional fit between the fitting surface of the crown and the tooth surface [6]. However, this theory has been rejected because a perfect fit could not be achieved during the cementation, due to the lack of space for the cement [7]. Die spacing allows increased space for the luting agent between the tooth preparation surface and the fitting surface of the crown, reducing stress areas formed during cementation, and thereby resulting in better fitness and retention of the definitive restoration [8]. Conversely, if the cement space was too wide, the seated crown will be loose on the tooth; their resistance to dislodgment will reduce. In addition, the risk of crown loosening during function will considerably increase, compromising its longevity [3].

Traditionally, definitive cementation is regarded as a fundamental step through restorative procedures. The proper selection of luting agent and the application of standardized cementation protocol are crucial for proper retention and adequate marginal sealing and of the restoration in time [9]. However, the decision considering which luting agent to use is also based on other factors. In general, the data suggest that adhesive resin based cement provide the highest retention [3].

The aim of this *in vitro* study was to evaluate the effect of different spacer thicknesses on the retentive strength of all-zirconia crown cemented with either conventional or self-adhesive cement.

PATIENTS AND METHODS

Total 24 sound 2 rooted maxillary first premolar teeth of comparable size and shape were extracted for orthodontic purpose in Basrah were collected and selected from patient age (18-24) years. The teeth were kept in deionized distilled water to prevent their dehydration during all stages of this study [10]. All teeth were mounted in auto polymerizing acrylic resin 2 mm apical to Cemento-Enamel Junction (CEJ) to simulate the level of supporting alveolar bone [11]. Prior to mounting the teeth, a U-shaped notch was made on each tooth roots to act as a mechanical mean for retention [12].

All teeth were prepared following the guidelines recommended for InCoris TZI C, (planner occlusal reduction, axial reduction 1 mm-1.5 mm, deep chamfer finishing line (0.8 mm) and one mm above the cemento-enamel junction, 4 mm occluso-gingival height). To achieve standardized preparation, a modified dental surveyor was used in order to hold the turbine handpiece in such a way so that the bur will be kept parallel to the long axis of the tooth during axial wall preparation. This was to ensure the same tapering angle for all teeth (6º total convergence angle) which depend on the taperness of the burs used [13]. A digital caliper was used to check these dimensions. All fabrication procedures including model scanning, software designing, milling, and sintering protocols were done according to the manufacturer instruction of zirconia (InCoris TZI C) and CAD-CAM milling system used. A 3-dimensional digital model for each tooth was taken using CEREC Omnicam digital intra-oral scanner. Measurement of the surface area (mm^2) of the scanned preparation was performed using Auto CAD architecture software.

Sirona in Lab CAD SW 16.1 was used to design the crown restoration. In the beginning, one reference crown was made and its morphology was applied to all other restorations to yield more accurate results [14]. The restoration parameter used in this study is that set by the manufacturer of CAD-CAM milling system InLab software 16.1. The teeth were divided equally into 3 groups of 8 each according to the die spacer thickness: Group A: 80 µm; Group B: 100 µm and Group C: 120 µm. The upper occlusal surface of the zirconia crowns was designed with 4 outer macro-retention bars on each side to provide retention during the dislodgment procedure.

The crown cementation procedure, using Self-adhesive resin cement (SARC) (Relyx unicem aplicap), was accurately carried out according to the manufacturer's instructions. Prior to cementation, two coats of Z-prime plus were used according to the manufacturers' instructions.

Custom made holding and cementation device was used in this study to maintain a constant seating force that was perpendicular to the occlusal surface of the crown during the cementation process [15,16]. A 5 Kg load (approximately 50 N) was applied in order to simulate the clinical condition during the cementation procedure "biting force" [17]. After cementation, the crowns were kept in distilled water for 1-week.

Before the tensile test, each crown was embedded in a clear cold cure acrylic resin block. At the same time, a screw was incorporated at the top of this block parallel to the long axis of the tooth. The entire apparatus was mounted in a screw-driven universal testing machine (Zwick Z010) and was pulled along the path of insertion of the restoration in a crosshead speed of 0.5 mm/min until failure. The dislodgment force was recorded and divided by the total surface area of each preparation to yield the retentive stress value (MPa).

The debonded surfaces of the teeth and crowns were examined using a magnifying lens. Each surface of the dentin-crown interface was analyzed individually. Failure was classified based on the criteria presented in Table 1 [12]. Retentive stresses were evaluated using two-way analysis of variance (ANOVA) and Post-hoc Bonferroni test at 0.05 level of significance.

Table 1 Classification of failure criteria

Classification	Description	Nature
1	Cement principally on the prepared tooth (>3/4 of the axial surface)	Adhesive
2	Cement on ceramic coping and tooth	Adhesive
3	Cement principally on ceramic coping (>3/4 of the axial surface)	Adhesive
4	Fracture of tooth or tooth removal	Cohesive
5	Fracture of coping	Cohesive

RESULTS

Descriptive statistics of the retentive strengths in all spacer groups are presented in Table 2, the highest mean of retentive stresses values was 7.360 MPa recorded for 80 µm spacer group. One way ANOVA test revealed a significant reduction in the mean crown removal stress in all spacer groups (p=0.001).

Table 2 Descriptive statistics of the retentive strength of three different spacer thicknesses measured in MPa

Groups	No.	Mean	± S.D.	Min.	Max.
80 µm	8	7.360	0.713	6.364	8.219
100 µm	8	5.909	0.963	4.461	7.396
120 µm	8	5.580	0.849	4.588	7.337

Post-hoc Bonferroni test revealed that the application of 80 µm spacer thickness resulted in significally higher means of retentive stresses than 100 µm and 120 µm spacer groups (p=0.001). However, a non-significant reduction in the mean crown removal stress when increasing spacer thicknesses from 100 µm to 120 µm (p=1.00) was observed as shown in Table 3.

Table 3 Post-hoc Bonferroni test for comparison of retentive strength among groups

Groups		Mean Difference	Sig.	95% Confidence Interval for Difference	
				Lower Bound	Upper Bound
80 µm	100 µm	1.452	0.010 [HS]	0.282	2.621
	120 µm	1.781	0.001 [HS]	0.612	2.950
100 µm	120 µm	0.329	1.000 [NS]	-0.840	1.498

The results for characterization of failure revealed that, generally, the predominant mode of failure was type 3, where the cement was found principally on the crown. This was followed by type 2, where cement was found on both the tooth and the crown restoration.

DISCUSSION

Zirconium oxide crowns were chosen for the present study due to excellent physical properties that were amenable to the tensile pull-off test [18]. Crowns were designed with 3 different cement space thicknesses using CAD software (80 µm, 100 µm, and 120 µm). It was assumed that by changing this space, the effect of the luting cement on the overall retention could be more accurately recognized [19].

Laboratories have developed crown pull-off tests in order to better simulate the physiological function. However, other bond strength test (shear, tensile, microtensile or push-out tests) does not reflect the clinical situation which is the main criticism from clinicians [4].

The most challenging part of the study that could greatly influence the result is how to hold the crown in place for the tensile pull-out test. Attention should also be paid to not include shear forces during the dislodgement of the crown the UTM. Therefore, a standardized and rigid apparatus has to be made to mount the specimen in the UTM and to connect the crown to the actuator part of the machine.

When comparing the retentive stresses of monolithic zirconia crowns using 3 different cement spacer thicknesses and single luting agent the results revealed that the highest mean retentive value was recorded in 80 µm spacer (Group A) (7.360 MPa) while the lowest mean retentive value was recorded in 120 µm spacer Groups (C) (5.580 MPa).

The results showed a statically highly significant reduction in the retentive stress when increasing the spacer thickness from 80 µm to 100 µm or from 80 µm to 120 µm. Increasing the crown spacer setting from 100 µm to 120 µm did not significally reduce its retention.

The ideal dimension for the cement space has been suggested at 20 μm to 40 μm per wall, which implies that an internal diameter of a complete crown should have between 40 μm and 80 μm greater than the diameter of the prepared tooth. If the luting agent space was too narrow, improper crown seating during cementation will occur. Conversely, if the luting agent space was too wide, the crown will be loose on the tooth and may be easily dislodged during function [3].

The effect of die-spacing on the retention of cemented crowns has been the subject of a number of studies. The results found in our study agree with that obtained by Vermilyea, et al., Gegauff, et al., Jorgensen, et al., Passon, et al., Juntavee, et al., [20-24]. However, it may be difficult to compare the results because the aforementioned studies were using a metal casting not a CAD CAM fabricated ceramic crowns.

Studies on die spacer produce conflicting results. This would suggest that its effect on crown retention remains incompletely determined. No clearly established experimental protocol is evident from the previous studies rendering comparison of results obtained from these studies so difficult. Further research into the effect of die-spacing on crown retention is required.

The mean of crowns removal stresses was comparable to that observed for gold casting when using zinc phosphate and glass ionomer blocks of cement, both with a long history of clinical success [25]. Thus, it appears that the retentive stresses values observed in our study were adequate to retain ceramic restoration successfully.

The results of this study could have important clinical implications since there has been a lack of clearly established standarized protocol with cementation of all zirconia crowns. The processes have been simplified to some extent since it was apparent that special treatment of the internal surface was not necessary for the cement evaluated (other than Z-prime application). It may be that the inherent roughness of ZrO_2 ceramics without airborne particle abrasion may be enough to provide the necessary micromechanical interlocking of the cementing agents.

Further research is needed to examine various surface treatments, long-term storage, thermocycling, various crown material types, and different luting cement. In addition, long-term prospective, randomized controlled clinical trials are needed to evaluate the benefits of certain clinical procedures, including for this innovative type of all-ceramic restoration.

CONCLUSION

Within the limitation of the *in vitro* study, the following conclusions were drawn:

- The use of 80 μm cement space thickness resulted in significantly higher retention than 100 μm and 120 μm spacer
- Increasing cement space from 100 μm to 120 μm did not yield a significantly lower retention value
- The retentive stresses values observed in our study were adequate to retain zirconia crown restorations successfully

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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