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RETENTION OF TWO ESTHETIC CROWN SYSTEMS

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ABSTRACT

Purpose: This in vitro study investigated the effect of intaglio surface conditioning and luting cements on retention of monolithic zirconia and metal-ceramic crowns.

Methods: First mandibular molars (n=96), periodontally compromised and indicated for extraction were collected from oral surgery department, faculty of dentistry, Mansoura University and prepared to receive metal-ceramic and zirconia crowns. Forty-eight zirconia copings (Z) with 0.5 mm thickness were fabricated from monolithic zirconia using CAD/CAM machine (Ceramill motion 2). While Forty-eight cast metal copings (C) with 0.5 mm thickness were laboratory fabricated from Ni-Cr alloy and veneered with ceramic (VITA VM9). Intaglio surfaces of zirconia and metal-ceramic crowns were airborne-particle abraded. Zirconia and metal-ceramic copings were divided into 2 groups (n=24). Universal primer (P) (Monobond N) was applied to subgroup (n=24) while the other 24 copings were left without primer application (NP). Each 24 copings were divided into 3 divisions (n=8) according to luting cements: Metacem (M), G-CEM (G) and Ketac Cem Plus (K). A total of 12 groups were tested: M-P-C, G-P-C, K-P-C, M-NP-C, G-NP-C, K-NP-C, M-P-Z, G-P-Z, K-P-Z, M-NP-Z, RG-NP-Z and K-NP-Z. Specimens were stored in water for 3 months interrupted with thermal cycling for 10000 cycles/month. Retentive strength in (N) was measured for each specimen. Statistical analyses were conducted using 3, 2 and 1-way (ANOVA) s and Tukey's HSD test.

Results: Means±SD retentive strength (N) of test groups were; Metacem (M): P -C, 756.8±96.3 > P-Z, 592.8±82.7 > NP-C, 582.7±79.9 > NP-Z, 499.7±58.6. G-CEM (G): P-C, 659.5±48.1> P-Z, 595.6±67.9 > NP-C, 543.5±56.5 > NP- Z, 467.3±68.5. Ketac Cem Plus (k): P-C, 539.9±76 > NP-C, 461.6±69.8 > P-Z, 455.9±66.7> NP-Z, 452.6±73. Primer application significantly ($P<0.05$) increased retention of all test groups. Luting cements increased retention of test groups as follow, M > G > K.

Conclusions: Primer application increased retention of both monolithic zirconia and metal-ceramic crowns. Multistep adhesive rein cement and self adhesive resin cement are the luting cements of choice for bonding monolithic zirconia and metal-ceramic compared to resin modified glass ionomer luting cement.

KEYWORDS: Metal-Zirconia-Crowns- Luting-Retention

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INTRODUCTION

Base metal alloys are used for fabrication of metal ceramic restorations because they have higher free-surface energy, hardness, higher modulus of elasticity, and superior sag resistance at elevated temperatures.[1, 2] Moreover metal ceramic restorations are used since over 40 years to restore anterior and posterior teeth due to their acceptable esthetic and high mechanical properties.[3] Therefore it is considered golden slandered for comparing durability of recently introduced metal free restorations.[3]

The increasing demand for esthetic and natural like appearance of restorations led to the development of zirconia ceramics[4, 5]. Recently monolithic zirconia are introduced in the dental market for restorations of anterior and posterior teeth.[6,7] Although retention of crowns depends on geometry of the prepared teeth surface, and taper angle[8,9] intaglio surface conditioning as well as luting cements are critical to clinical success and durability of cemented crowns.[10,11]

Air-borne particle abrasion is well established method for intaglio surface conditioning.[12-17] A lot of primers have been introduced into the dental market to achieve strong chemical adhesion to different ceramic and metal alloys such as Monobond N.[18-21]

Different luting agents are used for crowns cementation however, adhesive resin cement is preferred in many cases of poorly retentive restorations and resin-bonded fixed dental prosthesis.[12,23-25] On the other hand the complicated bonding procedures challenge the routine use of these cements.[26-29] Therefore many of recent self-adhesive resin cements have been introduced into the dental market to improve quality of bonding procedures through single clinical step.[29-33] The optimal goal for improving bonding performance of luting cements to fixed prosthetic materials and tooth structure is to improve durability of the definitive restoration.[27-29] Before performing clinical studies, in vitro studies should be undertaken to prove materials' applicability and performance, however in vitro studies should replicate clinical conditions.[34-36] Therefore long term storage in water and thermal cycling are important factors during in vitro studies.[1,16,34,35] Several in vitro studies investigated the effect of intaglio surface treatments as well as different luting cements on retention of different types of crowns.[1,2,4,5,10,11,16] However, no study has been published yet considering the effect of universal primer application and different luting cements on retention of monolithic zirconia crowns compared to metal ceramic crowns. Therefore the purpose of this in vitro study was to evaluate the influence of universal primer application (Monobond N) and 3 luting cements on retention of monolithic zirconia crowns with compared to metal-ceramic crowns.

The hypotheses of the study were that (1) primer application will not influence retention, and (2) also luting cements will not influence retention of monolithic zirconia crowns compared to metal-ceramic crowns.

MATERIAL AND METHODS

Ninety-six sound human first lower molars, periodontally compromised and indicated for extraction were collected from oral surgery department, faculty of dentistry, Mansoura University and cleaned from both calculus deposits and soft tissues, then kept in distilled water. Roots were roughened[1] and molars were fixed in metallic rings using self cure acrylic resin. The occlusal surfaces of molars were sectioned using a slow speed sectioning saw[1] (Isomet 1000, Buehler Ltd., Lake Bluff, IL, USA) perpendicular to the long axis of the ring and 5 mm above the top of the ring. Tooth preparation was performed using paralleling machine with a serial of diamond burs. The prepared teeth showed the following standardized preparation criteria: 12-degree axial taper, 1 mm axial reduction and 4 mm occluso-gingival height measured from the prepared finish line[1]. Prepared molars divided into

2 main groups (n=48) according to materials used for coping fabrication. A single-stage impression technique with putty and light bodied vinyl polysiloxane material (Lot 38371, alphasil, Muller-Omicrom, Lindler, Germany) was used for making impressions of the prepared molars. Definitive dies were prepared from these impressions using type IV extra hard stone (Kimberlit, Lot 20769, Vilamalla, Spain). Forty-eight CAD/CAM monolithic zirconia ceramic copings (Z) 0.5 mm thickness (Ceramill ZOLID 71 S, Amann Girrbach AG Koblach, Austria) (Table 1) were manufactured using a CAD/CAM machine (Ceramill motion 2, Amann Girrbach). The upper occlusal surface of the copings was designed with two extensions (2mm) on the distal and mesial surfaces of the coping (Fig. 1) to provide retention for the dislodgment apparatus[16]. While 48 cast metal copings (C) were waxed with 0.5 mm thickness at occlusal and axial wall. A wax loop was adhered to the wax pattern at the center of occlusal surface to provide retention for the dislodgment apparatus (Fig. 1).[1] Investing and casting using Ni-Cr alloy was performed according to manufacture recommendation.

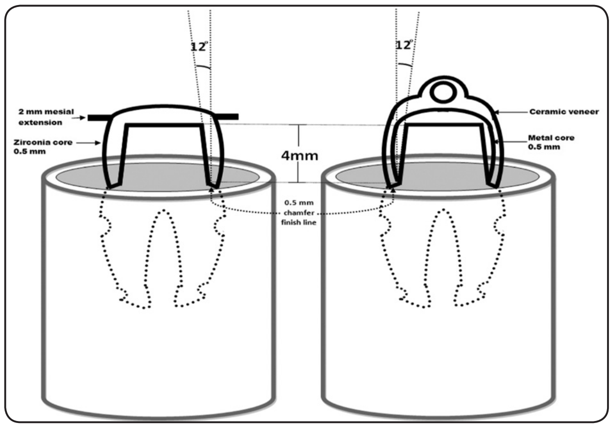

Fig. (1) Schematic diagram showing zirconia and metal-ceramic copings cemented to prepared molars.

TABLE (1) Materials used in the study

Material	Lot/Batch No	Manufacturer
Yttrium-stabilized (Y-TZP) monolithic zirconia ceramic with the following chemical composition, ZrO2 + HfO2 + Y2O3: ≥ 99,0, Y2O3: 4,5 - 5,6, HfO2: ≤ 5, Al2O3: ≤ 0,5, other oxides: ≤ 1	1512008-132 1512008-133	Ceramill ZOLID 71 S Amann Girrbach AG Herrschaftswiesen 1 Koblach, Austria
Ni-Cr Be free base metal alloy for all high-melting ceramics with the following composition: Ni 60%, Cr 26%, Mo12 %, Mn< 0.1, Si 1.5, C< 0.1and non specified values <= 0.1%	H09-22	Kera NH Eisenbacher DentalwarenED, Worth Germany
Alcohol solution of 3-methacryloxyprophyl-trimethoxysilane, phosphoric acid methacrylate and sulphide methacrylate	Lot V20475	Monobond N Ivoclar Vivadent, FL
Dual-polymerizing, self adhesive resin cement in capsule Liquid, contains water and functional monomers (4-MET and phosphoric acid ester), Urethane dimethacrylate (UDMA), Dimethacrylate, Silicon dioxide, initiator Powder, contains fluoroalumino silicate glass, Initiator and pigments	1202091	G-CEM Tokyo, Japan
Auto-polymerizing, radiopaque, fluoride- releasing, resin modified glass ionomer cement Paste A, fluoroaluminosilicate (FAS) glass, proprietary reducing agent, HEMA, water, opacifying agent	83921/PF13M	Ketac Cem Plus, 3MESPE,Seefeld Germany
Base, BisGMA, TEGDMA, Barium Aluminum borosilicate. Catalyst, BisGMA, TEGDMA, Barium Aluminum borosilicate	MF11061601	Metacem,META BIOMED, Chungbuk, Korea

Fit of each coping was checked on its respective prepared molar using an articulating paper. A round bur was used to remove the marked areas on the fitting surface. This procedure was repeated till complete seating of the coping on its respective prepared molar. The dentin and enamel layers of porcelain were build up on metal coping by mixing its powder and liquid then they were placed on a firing tray which carried out in VitaVacumat (Vita-In-Ceram, Zahnfabrik, Germany). The firing procedures were carried out according to the manufacturer recommendations.

Specimens cementation

The intaglio surfaces of metal-ceramic and zirconia copings were abraded using airborne-particle with 50 μm Al_2O_3 at 0.05 MPa for 15 seconds at a distance of 10 mm (Ney Blastmate II, Ney, Calif, USA).

Cleaning of specimens ultrasonically was performed using alcohol (99% isopropanol) for 3 minutes then dried using oil free blasting air for 15 s before bonding.

Both metal-ceramic and zirconia copings were divided into 2 equal subgroups (n=24) according to primer application as follow:

Universal primer (P) (Monobond N, Ivoclar Vivadent) was applied to the intaglio surfaces of 24 copings. The primer was applied in excess with a suitable disposable brush to react for 60 seconds[19, 21]. Finally the primer was distributed using oil-free air for 5 seconds[19, 21]. While the other 24 copings were bonded without primer application (NP). Prepared teeth were cleaned according to manufacturer instructions of each luting cement. Each subgroup was divided into 3 divisions (n=8) according to luting cements.

1. Metacem (M); dual-polymerizing, universal, in the form of two past adhesive resin cement, composed of BisGMA and TEGDMA (METACEM BIOMED). Etching gel 37% Phosphoric acid (METABIOMED) was applied to the adherent tooth surface for 15 seconds and dried with oil free air. Double layers of bonding agent (Meta P&Bond, METABIOMED) were applied for 5 minutes and gently air dried for 5 seconds followed by light curing for 10 seconds. Equal amounts of the luting cement were extruded, mixed for 20 seconds. The mix was applied to the intaglio surface of zirconia and metal-ceramic copings.
2. Ketac Cem Plus (K); auto-polymerizing, resin modified glass-ionomer cement with BisGMA and HEMA in its composition. (3M ESPE). Equal amounts of past A &B were dispersed and mixed for 20 seconds on waxed paper pad, with a plastic spatula until a creamy mix with a uniform color was obtained. The mix was applied onto the fitting surface of both zirconia and metal-ceramic coping.
3. G-CEM (G); dual-polymerizing, self adhesive resin cement in capsule contains water and functional monomers (4-MET and phosphoric acid ester), Urethane dimethacrylate (UDMA), and fluoroalumino silicate glass. The mix started by activation of capsule for 4 seconds then completed in an amalgamator for 6 seconds. The mixed cement was applied directly onto the intaglio surfaces of each zirconia and metal-ceramic coping. Each coping was inserted on its respective prepared molar. Each specimen was kept under a static load of 20 N for 10 minutes. Excess luting cement at the margin was removed. A combination of coping materials, luting cements and primer application resulted in 12 test groups: M-P-C, G-P-C, K-P-C, M-NP-C, G-NP-C, K-NP-C, M-P-Z, G-P-Z, K-P-Z, M-NP-Z, G-NP-Z and K-NP-Z. To simulate intraoral conditions, one hour after cementation, specimens were stored in distilled water bath at 37°C for 3 month interrupted by thermal cycling between 5°C and 50°C in distilled water with a dwell time of 1 minute (Willytec, Munich, Germany) for 10000 cycles. Copings were dislodged from their respective teeth using a universal testing machine (Type 500, Lloyd Instrument, Farnham, UK). A tensile force was

applied at 0.5 mm/min crosshead speed until separation occurred. Retentive strength in (N)[1] was recorded for each specimen. Three and Two-way analysis of variance (ANOVA) followed by serial one-way (ANOVAs) at each level of the study, core materials, primer application and luting cements. Finally Post Hoc Tukey test at (P<.05) were used for testing significant difference between each two test groups.

RESULTS

Mean retentive strength was evaluated and compared across test groups with a three-factor ANOVA model, including the following factors: Coping materials, application of primer, and luting cements and their interactions. The overall ANOVA F-test (Table 2) was highly significant (*P*<.0001), indicating differences in mean retentive strength across at least one of the factors. Coping materials, primer application and luting cements were significant (*P*<.0001). However the interaction between coping materials, primer application and luting cements was not significant (P=.6).

Further analyses with serial 2-way ANOVAs (Table 2) were performed including the following factors: primer application x coping materials, primer application x luting cements and coping materials x luting cements. Interactions of coping materials x luting cements (*P* =.35) and primer application x luting cements (*P* =.6) were not significant. However the interaction of primer application x coping materials was significant (*P* =.03). A significant interaction between primer application and coping materials (*P* =.03), complicated the interpretation of retentive strength results. Therefore, to evaluate and determine which factor had the main effect on retentive strength value, further analyses with serial one-way ANOVA model were used to test the effect of each factor independently (Table 3).

Several comparisons with Post Hoc Tukey-HSD test at (α=0.05) were used to compare mean retentive strength of test groups (Fig.2). Primer application significantly increased mean retentive strength of the following test groups (M-NP-Z/M-P-Z; *P*=.04), (M-NP-C/M-P-C, *P*<.001), (G-NP-Z/G-P-Z; *P*<.001) and (G-NP-C/G-P-C; *P*=.002). However there was no statistically significance difference between the following test groups (K-NP-C/K-P-C; *P*=.07) and (K-NP-Z/K-P-Z; *P*=.7). Considering luting cements Metacem and G-CEM significantly increased retentive strength of all test groups compared to Ketac Cem Plus *(P*< 0.05) regardless of primer application.

Table 2. Summary of 3 and 2-way ANOVAs

By Level	Sum of Squares	Df	Mean Square	F	P-Values
Overall					
Coping material	238712	1	238712	11.9	P<.0001
Priming	219247	1	219247	37.4	P<.0001
Luting cements	216568	2	108283	18.7	P<.0001
Cement*Priming	8696	2	4348	.761	.47
Coping material* Priming	42485.3	1	42485.3	7.2	.008
Coping material * Cements	19039.6	2	9518.9	1.6	.2
Coping Mat *Priming*cement	5900.6	2	2953	.52	.6
Error	480192	83	5716.4		
Total	3.031E6	96			

By Level	Sum of Squares	Df	Mean Square	F	P-Values
Total (Corr.)	1230835	95			
Priming	219249	1	219249	27.6	P<.0001
Coping material	238704	1	238704	30	P<.0001
Coping material *Priming	42485	1	42485	5.4	.02
Error	730395	92	7936		
Total	3.031E6	96			
Total (Corr.)	1230831	95			
Priming	219248	1	219248	24	P<.0001
Cements	216564	2	108281	12.2	P<.0001
Cements*Priming	8695	2	4347	496	.61
Error	786322	90	8736		
Total	3.031E7	96			
Total (Corr.)	1230834	95			
Cements	216564	2	108282	12.8	P<.0001
Coping material	238705	1	238703	28.6	P<.0001
Cements * Coping material	19036.6	2	9516.5	1.1	.33
Error	756525	90	8405		
Total	3.031E6	96			
Total (Corr.)	1230834	95			

TABLE (3) Serial 1-way ANOVAs at each level of the study

By Level	Sum of Squares	Df	Mean Square	F	P-Values
Luting cements					
Metacem	458272.6	3	152755.7	6.7	.002
RelyX Unicem	266146.5	3	88715.4	4.7	.007
Ketac Cem Plus	255183	3	85063	3.27	.04
Coping materials					
Zirconia	40218	5	8041	.66	.68
Metal-ceramic	175675	3	58556	5.3	.006
Priming					
No primer application	218176	5	43644	3.5	.02
Primer application	462748	5	92556	7.5	<.001

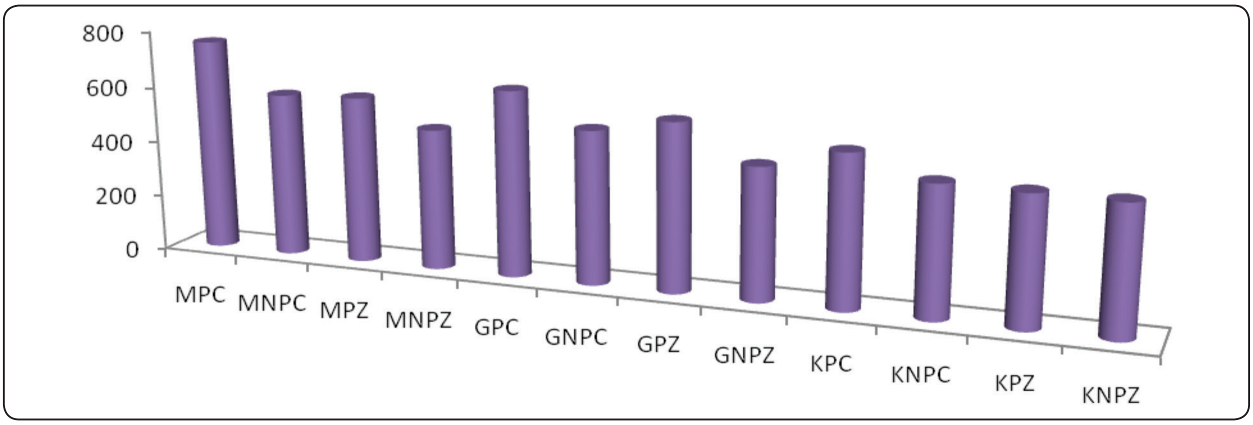

Fig. (2) Cylindrical graph represent mean retentive strength of all test groups in (N)

DISCUSSION

In this in vitro study specimens were subjected to 10,000 thermal cycles. Gale and Darvell[34] mentioned that 10,000 thermal cycles were chosen so as to equal one year's clinical service. Retentive strength of zirconia and metal-ceramic copings were influenced by the universal primer application and the luting cements.

The optimal goal for improving bonding performance of luting cements at tooth/restoration interface is to improve durability of the final restoration in term of retention.[1,29,32] Currently accepted cementation protocols of fixed dental prosthesis includes air-borne particle abrasion of the intaglio surface followed by application of different primers to achieve a combination of micromechanical and chemical bonding. [1, 11-13, 16, 18-21].

Ultrasonic cleaning of the copings was created to achieve adequately cleaned intaglio surfaces to improve bonding durability and retention [1, 12, 13, 16]. Air-borne particle abrasion produced micropores in the intaglio surface, increased total bonding surface area and increased wettability of the intaglio surfaces, consequently improved the formation of micromechanical interlocking at intaglio surface/luting cement interface.[1, 12, 13, 16]

According to the manufacturer universal primer (Monobond N) composed of a silane and a phosphate monomer. A strong chemical bonding due to conventional silane and phosphate monomer included the chemical composition of the primer plus improving wetability and surface energy of the intaglio surface increased retention of zirconia and metal-ceramic copings [18,19,21]. Consequently a double effect resulted from of micromechanical interlocking and chemical bonding improved the overall retention[18, 19, 21].

Considering the 3 luting cements used, Metacem and G-CEM increased retention of metal-ceramic and zirconia copings compared to Ketac Cem Plus. Variations in mechanical properties, chemical composition, wetting ability plus resistance to thermal stress of each luting cement might be responsible for these results.[1, 19, 36]. According to data supplied by the manufactures of each luting cement it is clear that mechanical properties of both G-CEM and Metacem are higher than that of Ketac Cem Plus. Flexural strength of Metacem is (99 MPa) and for G-CEM is (75 MPa) while for Ketac Cem Plus is (31.6 MPa). Attia[1] reported that luting cements with improved mechanical properties resulted in higher retentive strength under the same aging conditions.

Moreover chemical composition of each luting cement plays an important role in bonding ability and retentive strength of definitive restorations. G-CEM contains functional monomers 4-MET and phosphoric acid ester plus fillers in its chemical composition. Adhesive phosphate monomer was responsible for formation of strong hybrid layer with dentin.[30,31,33] Another possibility could be that acidic monomer incorporated in G-CEM formed a chemical bond to dentin through reaction with Ca ions in hydroxyapatite of tooth substrate.[1] Therefore a combination of micromechanical and chemical bonds to dentin were formed when G-CEM luting cement was used.[1] Another action of adhesive phosphate monomer was enhancing chemical bonding to intaglio surfaces of metal-ceramic and zirconia copings[18,19,21]. Before bonding with Metacem, etching with phosphoric acid demineralized dentinal tubules and created micropores. When bonding agent was applied it infiltrated dentinal tubules. Finally when Metacem mix was applied it flowed easily inside these dentinal tubules and formed a durable micromechanical resin tags. The fact that Metacem contains BisGMA, TEGDMA and barium aluminum borosilicate. These components improved its inherent mechanical properties, (99 MPa flexural strength) and its retention compared to G-CEM (75 MPa flexural strength) and Ketac Cem Plus (31.6 MPa flexural strength). The decreased retention of G-CEM compared to Metacem could be attributed to its low mechanical properties. Moreover according to the manufacturer, G-CEM contains UDMA in its chemical composition. Other studies reported that self adhesive resin cements containing UDMA showed higher water sorption compared to other adhesive resin cements.[1,23] Ketac Cem Plus luting cement resulted in significant low retention compared to results of the other 2 luting cements this, might be due to its inherent low mechanical properties and chemical composition. Ketac Cem Plus is glass ionomer cement modified with BisGMA, and HEMA. Several studies reported that resin modified glass ionomer cements are sensitive to water with a marked negative effect on its mechanical properties due to hydrothermal degradation and swelling stresses[12, 35, 36]. The hydrolytic effect of water, and thermomechanical stresses could explain the significant low retention of Ketac Cem Plus compared to Metacem and G-CEM. The results of this in vitro study were in agreement with the results of other study[11] which compared retention of metal-ceramic crowns cemented with resin modified glass ionomer cement compared to adhesive resin cement and self adhesive resin cement. Clinically the complex nature of thermomechanical stresses could negatively influence retention of crowns. Such conditions could not be really replicated in this study. Therefore long term clinical study should be conducted to prove the results of this in vitro study.

CONCLUSIONS

Allowing for the limitations of this in vitro study, the following conclusions were drawn:

1. Application of universal primer is mandatory step to increase retention of metal-ceramic and zirconia crowns before definitive cementation.
2. Multistep and self adhesive resin cements increased retention of zirconia and metal-ceramic copings compared to resin modified glass ionomer.

3- Type of coping materials used has no effect on the final retention

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