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Marginal Fit and Retention Strength of Zirconia Crowns Cemented by Self-adhesive Resin Cements

R Pilo • M Folkman • A Arieli • S Levartovsky

Clinical Relevance

The marginal fit of zirconia crowns cemented by self-adhesive resin cements is clinically acceptable, but the retention after severe aging processes is unsatisfactory.

SUMMARY

The absolute marginal gap (AMG) precementation and postcementation and the retention of zirconia crowns cemented to standardized molar preparations (4×10) by self-adhesive resin cements (SARCs) were evaluated. The following SARCs were used: RelyX U-200 (RXU200; 3M ESPE, Seefeld, Germany), SmartCem 2 (SC2; Dentsply, Milford, DE, USA), and G-Cem Automix (GCA; GC, Alsip, IL, USA). The control adhesive resin cement was Panavia 21 (PAN; Kuraray Dental Co Ltd, Osaka, Japan). Twenty measuring locations at a constant interval along the margins were marked, and the AMG was measured by an image analysis system connected to a stereomicroscope (20×). The cemented copings were aged 270 days at 100% humidity and 37°C and then underwent 10,000 thermal cycles, 5°C-55°C. After aging, the crowns were tested for retention, and the debonded surfaces were examined at 3× magnification. The mean marginal gaps precementation and postcementation were 34.8 ± 17.4 μm and 72.1 ± 31 μm, respectively, with no statistically significant differences between the cements. A significant difference ($p \leq 0.001$) in retention between the cements was found. The highest values were obtained for SC2 and GCA (1385 Pa and 1229 Pa, respectively), but these presented no statistically significant differences. The lowest values were found for PAN and RXU200 (738 Pa and 489 Pa, respectively), but these showed no statistically significant differences. The predominant mode of failure in all of the groups was mixed, and no correlations were found between marginal gap and retention.

*Raphael Pilo, DMD, PhD, Department of Oral Rehabilitation, Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel

Merav Folkman, DMD, Department of Oral Rehabilitation, Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel

Adi Arieli, DMD, Department of Oral Rehabilitation, Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel

Shifra Levartovsky, DMD, Department of Oral Rehabilitation, Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel

*Corresponding author: Ramat Aviv, Tel Aviv, 69978 Israel; e-mail: rafipilo@post.tau.ac.il

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INTRODUCTION

All-ceramic indirect restorations, especially those of high-strength ceramic materials such as zirconia, offer esthetically pleasing restorations, even for long-span, fixed partial dentures (FPDs)[1]; however, their use has made luting procedures more challenging. The aim of cementation is to integrate the restorations with the dental hard tissues, especially with the dentin, supplying retention, marginal sealing, and esthetics.

Zirconia FPDs can be luted with conventional cements (zinc phosphate cement and glass ionomer) only if the appropriate tooth preparation provides sufficient retention. However, the introduction of cements with adhesive capabilities to dental practice has given practitioners the opportunity to increase retention in many other clinical situations (eg, short or tapered tooth preparation) and achieve the desired optimal esthetic results. As a result, particle-reinforced resin composite materials are presently the luting materials of choice. Adhesive bonding systems and resin cements demonstrate superior mechanical properties and stability,[2] reduced solubility,[3] high adhesive strength to restorative materials and dental hard tissues, and improved esthetics.[4] However, the complexity involved in multi-step systems requires simplification to reduce their technical sensitivity and chairside time.[5] Thus, self-adhesive resin composite cements (SARC), which do not require dentin pretreatment, have been developed.[6]

The main components of SARCs are as follows: 1) aromatic and aliphatic dimethacrylate monomers to form a cross-linked network, 2) acidic methacrylate monomers to adhere with enamel and dentin and copolymerize with the cross-linking monomers, 3) glass filler particles or basic compounds to neutralize residual acidic monomers, 4) conventional silanated filler particles to provide strength by an inert reinforcing effect, 5) appropriate catalysts and stabilizers to comply with the dual-cure characteristic and shelf-life requirements, and 6) pigments and opacifiers to fulfill the esthetic requirements.[7,8] The retention strength and marginal fit of zirconia-based ceramic restorations luted by SARCs were extensively investigated as independent variables. Palacios and others[9] reported no statistically significant differences in crown retention values luted by composite resin cement with adhesive agent (Panavia F 2.0 and ED Primer A & B), a resin-modified glass ionomer cement (Rely X Luting), and a SARC (RelyX Unicem). A nonsignificant difference between Panavia F 2.0 and RelyX Unicem was also reported in other studies,[10,11] irrespective of the internal surface treatment of the crowns.[11] The retention was higher only when the RelyX Unicem Aplicap was used[10] and lower when total-etch adhesive resin cement (Duo-Link) was used without crown surface treatment.[10] Ernst and others[12] tested the retention strengths of four resin-cement systems as well. They also found no significant differences in the retention strength values between the compomer, the resin-modified glass ionomer, the SARC, and the adhesive resin luting cements Superbond C&B and Panavia F 2.0.

Three different parameters of marginal fit have been traditionally defined in the literature: *vertical marginal discrepancy* measured parallel to the path of draw of the casting and *horizontal marginal discrepancy* measured perpendicular to the path of draw of the casting. The angular combination of the vertical and horizontal marginal discrepancies has been classified as the *absolute marginal discrepancy*.[13] These terms are difficult to define in underextended and overextended cases without sectioning. For simplicity, most current clinical studies divide these parameters into the following: *marginal gap* (vertical marginal discrepancy), which is the perpendicular distance from the internal surface of the coping to the margin of the preparation, and *absolute marginal gap* (AMG; absolute marginal discrepancy), which is the distance from the external edge of the coping margin to the cavosurface of the preparation finish line.[14-16] The latter definition was adopted in the current study.

The marginal fit is still one of the most important criteria for the clinical success of all-ceramic FPDs. A large marginal discrepancy can compromise the longevity of the restoration, not only because of caries but also because of periodontal disease.

Copings of zirconia-based ceramic restorations are routinely produced by computer-aided design and computer-assisted manufacturing (CAD-CAM). These CAD-CAM restorations are popular because they provide reproducible results with high esthetic value, short fabrication time, and reduced technical errors.[15] Numerous studies have reported an absolute marginal discrepancy of <90 μm with various CAD-CAM systems,[16-20] all within the acceptable clinical limit of 120 μm;[17,21] however, few have tested this variable precementation and postcementation.[17,22]

The marginal seal capability of cemented all-ceramic crowns with self-adhesive resin cement in comparison with other cements is still under study. Yuksel and others[23] reported a lower level of microleakage with the SARC compared with glass ionomer luting cement. Similarly, Behr and others[24] have reported that the SARC had significantly lower dye penetration in comparison with resin cement with a smear layer–removing adhesive system and compomer cement with a smear layer–dissolving adhesive system. Ghazy and others[25] have demonstrated that the resin cement with separate primer/bonding agent results in significantly lower microleakage scores, irrespective of crown material. Rosentritt and others[26] have found no significant difference in marginal integrity between the SARC and conventional resin cements after total etching, priming, and bonding.

Although the marginal seal is a cement material–dependent property, it is strongly linked to the marginal gap precementation and postcementation because the higher the marginal gap, the less probability of perfect sealing. The marginal gap of cemented CAD-CAM zirconia-based FPDs depends on the design of the finishing line,[19] the impression technique,[20] the type of system used,[16,17] and the cement space.[27] Given that the aim of cementation is to concomitantly enhance the retention and marginal fit, these variables should be investigated in the same study. However, no study has addressed both of these variables in CAD-CAM zirconia-based FPDs cemented by SARCs.

Therefore, the aims of the current study were 1) to evaluate the marginal fit of CAD-CAM zirconia crown copings before and after cementation by three types of SARCs and a control adhesive resin cement; 2) to test the retention strength of these crowns postcementation; and 3) to correlate the marginal fit with the retention values.

The null hypotheses tested were as follows: 1) there is no difference in AMG before or after cementation or in retention between the different cements; and 2) no relationship between retention and marginal fit exists.

METHODS AND MATERIALS

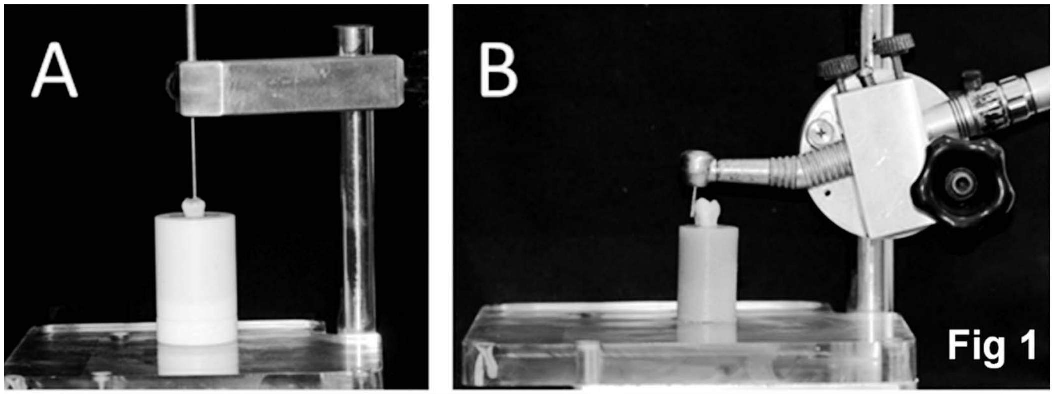
A total of 40 freshly extracted, caries-free, intact molars were collected for the study. The study protocols were approved by the Tel Aviv University Ethics Committee. The patients were informed about this study and consented to the use of their teeth. All external debris was removed by curettes, and the teeth were stored in a germ-free 0.1% thymol solution at room temperature for three days. They were then switched to tap water for no longer than three months until experimentation. The roots of the teeth were notched for retention purposes by a diamond bur (C1, Strauss, Ra'anana, Israel) and embedded parallel to the long axis of the tooth with a custom-designed alignment apparatus. Each tooth was suspended in the middle of a polytetrafluoroethylene (Teflon) ring and mounted 2 mm apical to the cementoenamel junction (CEJ) in a polymethyl methacrylate resin (Quick Resin, Ivoclar Vivadent, Schaan, Liechtenstein) (Figure 1a). After mounting, the teeth were stored in tap water at room temperature.

All teeth were prepared according to the following standardized protocol. The occlusal surface was sectioned perpendicular to the long axis, 6 mm above the CEJ, with a water-cooled precision saw (Isomet Plus, Buehler, Lake Bluff, IL, USA). A 0.4-mm, 360° chamfer finish line located 1 mm above the CEJ with a 10° taper was prepared with a rigidly secured high-speed handpiece equipped with a diamond bur (C1, Strauss) mounted on a custom-designed surveyor-like apparatus (Figure 1b). Final preparation took place exclusively in dentin, and a new bur was used for each tooth.

Impressions of the prepared teeth were made using a two-step technique. The preliminary impression was made with a copper ring filled with an acrylic material (Unifast, GC, Alsip, IL, USA). In the second step, an acrylic layer with a thickness of 2 mm was removed from the inner aspect of the ring, and an occlusal vent hole was created. A condensation silicone wash impression material (Xantopren, Heraeus Kultzer, Hanau, Germany) was dispensed with an automatic mixing syringe. To compensate for the difference between room and mouth temperatures, the setting time was doubled. The impressions were poured with a type 4 dental stone (Silky Rock, Whip Mix, Louisville, KY, USA) mixed with a Multivac (Degussa, Essen, Germany) on a vibrating machine (Sun, Barst, Las Vegas, NV, USA).

A total of 40 crown copings were produced using CAD-CAM technology with Lava frame zirconia blocks (3M ESPE, Seefeld, Germany). The Lava CAD-CAM system includes an optical scanner (Lava Scan), a CAM machine (Lava Form), and a sintering oven (Lava Therm). CAD-CAM zirconia copings of 0.5-mm axial and 1.0-mm occlusal thickness were milled at a commercial dental laboratory (Lava Milling Centre, Dental Centre, Tel Aviv, Israel). A virtual spacer layer of 50-μm thickness 0.5 mm short of the margins was planned. The Lava zirconia coping was designed with a loop (4-mm outer diameter and 2-mm inner diameter) extending coronally from the occlusal surface (Figure 2a).

Prior to cementation, the areas of the axial and occlusal surfaces of each prepared tooth were measured as previously described by Pilo and



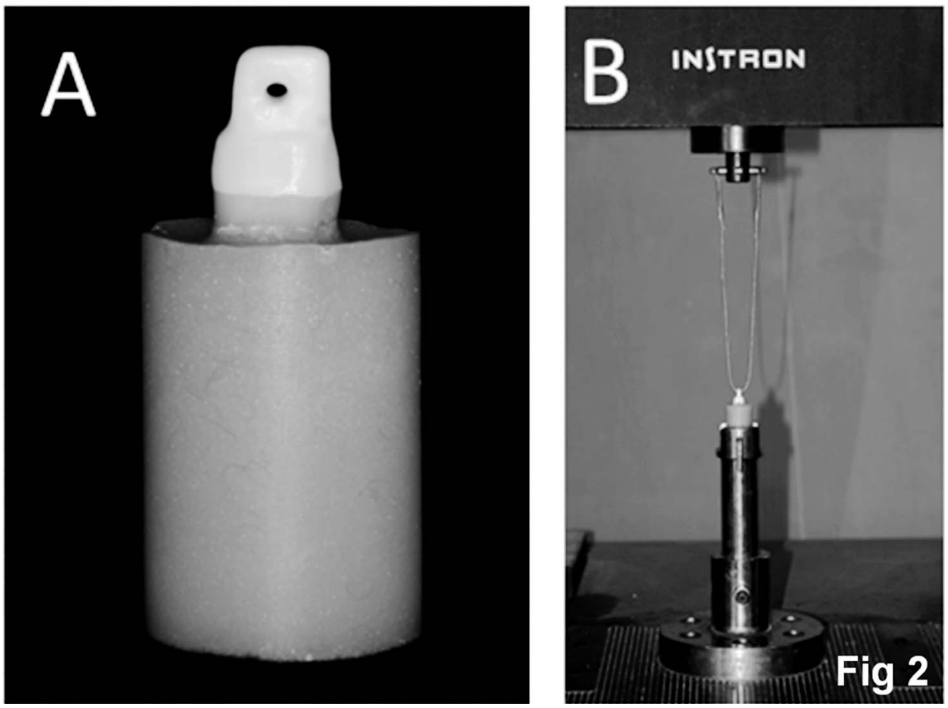


Figure 1. *Sample preparation. (A): Teeth were suspended in the middle of a polytetrafluoroethylene (Teflon) ring and mounted 2 mm apical to the cementoenamel junction in a polymethyl methacrylate resin. (B): Surveyor-like apparatus for the standardized preparation of mounted extracted teeth.*

Figure 2. *Retention strength experiment. (A): Zirconium oxide coping showing the design of the occlusal surface. (B): Metal cable connecting the coping with the universal testing machine.*

others[28] The AMG precementation was measured with a Bioquant Osteo image-analysis system using digital photographs acquired with a stereomicroscope (20×, M8, Wild, Heerbrugg, Switzerland). For all measurements, the specimens (copings on respective teeth) were placed on a metal device to secure the copings while applying a uniform load of 10 N. The marginal gap was measured at 20 measuring locations at an approximately constant interval along the margins of the tooth. The mean marginal gap width for each tooth was calculated. The locations were marked by an indelible marking pen (Lumocolor Permanent, Staedtler Mars GmbH, Nürnberg, Germany).

The 40 prepared teeth were randomly assigned to four groups (4×10: 3 SARCs and a control), according to the cement type used: RelyX U-200 (RU200; 3M ESPE, Seefeld, Germany), SmartCem 2 (SC2; Dentsply, Milford, DE, USA), G-Cem Automix (GCA; GC, Alsip, IL, USA), and Panavia 21 (PAN; Kuraray Dental Co Ltd, Osaka, Japan) (Table 1). The intaglio surfaces of the crowns were not sandblasted but were cleaned with Ivoclean (Ivoclar Vivadent). All cements were mixed following the manufacturers' instructions. The cement was placed on half of the axial surfaces of the copings, simulating the clinical procedure. Each coping was aligned and seated on the respective tooth with firm

Table 1: *Resin Cements, Manufacturers, and Chemical Composition*

Resin Cement	Manufacturer	Composition
RelyX U200	3M ESPE, Seefeld, Germany	Methacrylate monomers containing phosphoric acid groups, methacrylate monomers, silanated fillers, initiator components, stabilizers, rheologic additives, alkaline fillers, pigments
SmartCem 2	Dentsply, Milford, DE, USA	Urethane dimethacrylate, phosphoric acid-modified acrylate resin, barium boron fluoroaluminosilicate glass, organic peroxide initiator, camphorquinone, phosphene oxide, accelerators, butylated hydroxytoluene, UV stabilizer, titanium dioxide, iron oxide, hydrophobic amorphous silicon dioxide
G-Cem Automix	GC, Leuven, Belgium	Fluoroaluminosilicate glass, initiator, pigments, 4-META, phosphoric acid ester monomer, water, UDMA, dimethacrylate, silica powder, initiator, stabilizer
Panavia 21 + ED Primer A&B	Kuraray Dental Co Ltd, Osaka, Japan	HEMA, MDP, 5-NMSA, water, accelerator, ethanol, MPTS, initiator
		MDP, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, fillers, BPO, hydrophilic aliphatic dimethacrylate, hydrophilic dimethacrylate, sodium aromatic sulfonate

Abbreviations: BPO: benzoyl peroxide, *HEMA:* hydroxylethyl methacrylate, , *MDP*: methacryloyloxydecyl dihydrogen phosphate, *4-META*: 4-mathacryloylethyl trimellitate anhydride, *MPTS*: methacryloyloxypropyltrimethoxysilane, *5-NMSA*: 5-N-methacryloyl 5-aminosalicylic acid, *UDMA*: urethane dimethacrylate,

finger pressure according to the previously made markings and mounted under a constant load of 50 N (force gauge FG 20, Lutron, Taipei, Taiwan) for 10 minutes. The excess cement was removed with an explorer.

Marginal gaps were measured at the same locations with the same methodology 24 hours postcementation.

The cemented copings were stored in 100% humidity at 37°C for 270 days and subsequently underwent thermal cycling between temperatures of 5°C and 55°C for 10,000 cycles with a 10-second dwell time (Y. Manes, TA, Israel). The crown copings were subjected to dislodgment forces through a 1.2-mm diameter metal cable entangled through the coronal loop along the apico-occlusal axis until failure using a universal testing machine (Model 4502, Instron Corp, Buckinghamshire, UK) at a crosshead speed of 1 mm/min (Figure 2b). The force at dislodgment was recorded and divided by the total surface area of each preparation to yield the retention values (Pa).

Examination of the debonded surfaces of the teeth and crowns was performed under 3× magnification (Orascoptic HiRes 3, Middleton, Wi, USA). Each matched surface of the dentin-crown was analyzed separately (five surfaces per tooth).

Failure was classified according to the criteria presented in Table 2.

The data for the AMG precementation and postcementation were analyzed using a two-way analysis of variance (ANOVA) with repeated measures. The dependent variable was the mean marginal gap. The type of cement (n=4) and precementation/postcementation (n=2) served as the independent variables.

The data for the retention strength were analyzed using a one-way ANOVA with repeated measures. The Scheffé test for multiple comparisons was used; the dependent variable was the mean retention strength, and the independent variable was the type of cement used. The significance level for both tests was set to α=0.01.

Premarginal and postmarginal gap values were correlated to the respective retention values with the Pearson correlation coefficient. The significance level was set at α=0.05.

RESULTS

Table 3 presents the mean AMG (±SD) before and after cementation of all cementation groups, which for all groups combined were 34.83 ± 17.4 μm and 72.00 ± 31.22 μm, respectively. Analysis of variance

Table 2: *Classification of Failure Criteria*

Criteria	Description
Mixed mode	Adhesive and cohesive cement equally
Mixed (crown dominant)	Mixed but mainly adhesive cement-crown
Mixed (dentin dominant)	Mixed but mainly adhesive cement-dentin
Adhesive cement-dentin	Cement principally on crown surface
Adhesive cement-crown	Cement principally on dentin surface
Cohesive cement	Cement equally distributed on dentin and crown

Table 3: *Mean and Standard Deviation (SD) for Absolute Marginal Gap Before and After Cementation of All Cementation Groups*

Cement	Precementation	SD	Postcementation	SD
RelyX U-200	31.5	15.03	69.9	30.06
SmartCem 2	31.9	10.74	74.1	20.66
G-Cem Automix	43.3	20.16	76.1	32.17
Panavia 21	32.4	21.36	68.0	42.57
Total	34.8	17.40	72.0	31.22

with repeated measures revealed that this difference was statistically significant ($p<0.001$).

However, within each of the four cementation groups, the difference in AMG precementation (ie, as fabricated) and postcementation (ie, influence of the cements) was not statistically significant ($p=0.454$), and no interaction was found between the times (pre/post) and cements (0.379).

Figure 3 presents the mean retentive strength (±SD) for the different cementation groups. There were significant differences ($p\leq0.001$) in mean coping removal stress among the different groups. The highest mean dislodgment stresses were observed for SC2 and GCA (1385±615 Pa and 1229±491 Pa, respectively), which were not significantly different from each other, followed by 738±395 Pa for PAN and 489±265 Pa for RXU200, which were not significantly different from each other.

The failure modes of the different cementation groups are presented in Figure 4. Examination of the failure mode under magnification revealed that the main mode of failure for all cementation groups was mixed mode or mixed (crown dominant), implying that the failure was between the cement and crown in most surfaces, and thus most of the cement was trapped on the dentin. However, the cement group with the lowest retentive values, RXU200, was the only group to exhibit the pure adhesive cement-crown mode of failure (50%), whereas the groups with the highest retentive values, GCA and SC2, were the only ones to exhibit the pure adhesive cement dentin mode of failure, in 50% and 25% of the surfaces, respectively. PAN exhibited equal failure in mixed mode and mixed (crown dominant). SC2 was the only cement exhibiting the mixed (dentin dominant) mode of failure (approximately 30%).

The Pearson correlation coefficient test yielded nonsignificant low correlations between the before ($r=-0.14$, $p=0.37$) and after ($r=-0.33$, $p=0.17$) AMG values and their respective retentive values. The differences between the after and before AMG values and the respective retentive values also gave low, nonsignificant coefficients ($r=-0.34$, $p=0.11$).

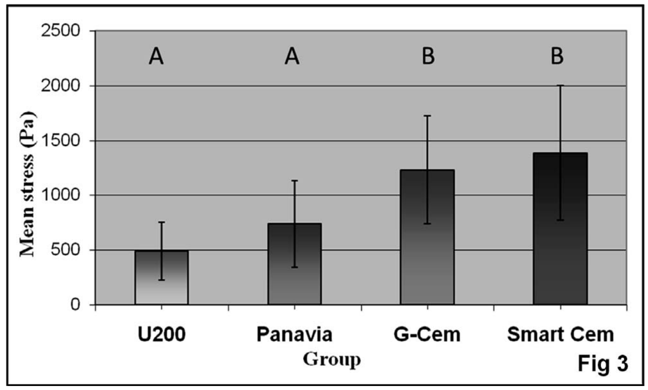


Figure 3. *The mean retention strength (Pa) (±SD) for the different cementation groups. Groups with identical letters presented no statistically significant differences.*

DISCUSSION

The AMG of the zirconia crown copings (CAD-CAM) examined before and after cementation did not differ significantly among the four cements examined. The results thus support our first null hypothesis. The mean AMG values of 35 μm precementation and 72 μm postcementation are all within the limits of clinical acceptability. A limit of up to 120 μm was first set for cast gold copings[29,30] but is also widely accepted for all-ceramic crowns.[17,21]

The AMG depends on the type of system used.[16,17] Our results with Lava correspond well to previous reports of 24-87 μm for this system.[15,19,31-33] Karatasli and others[15] compared the marginal adaptation of Lava copings (CAD-CAM) with that of Celay and Zirkonzahn copings (MAD/CAM), with casted metal copings as the control. The lowest marginal gap was observed in the Lava copings (24.6±14.0 μm), whereas the highest marginal gaps were observed in the Zirkonzahn (112.11±22.6 μm) and metal (120.1±33.1 μm) groups. Another study[34] that examined three different all-ceramic systems manufactured by CAD/CAM showed that the Lava system produced gap measurements (approximately 46 μm) that were statistically smaller than those obtained using the Everest (65 μm) and Procera systems (approximately 62 μm). Reich and others[35] compared the marginal gap of Lava three-unit FPDs (65 μm) with those of conventional FPDs (54 μm) and concluded that the clinical fit of all CAD/CAM systems tested competed well with that of conventional systems. The small differences in marginal

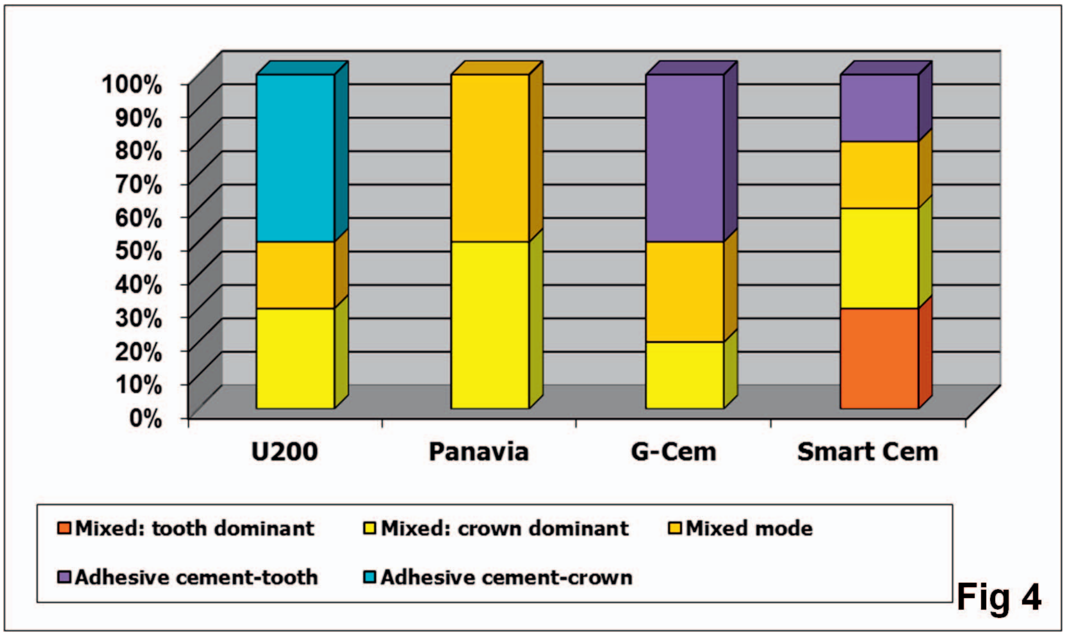


Figure 4. *The failure modes of the different cementation groups.*

gaps among the aforementioned studies are attributable to either variations in fabrication or differences in the virtual cement space,[27] which was not reported in most research. In our study, a virtual spacer width of 50 μm was set 0.5 mm short of the margins.

The AMG should be examined before and after cementation because elevation of the crown might occur during cementation, resulting in open margins and exposure of a large amount of cement to oral fluids.[36] Incomplete seating of crowns postcementation has been extensively studied and reviewed[37] for cast metal–based crowns. The complications caused by incomplete seating include the creation of premature contacts, alteration of contact areas, reduction of retention, and dissolution of extra cement with secondary caries.[37] However, few studies have examined the marginal gaps of all-ceramic crowns precementation and postcementation.[17,22]

Gonzalo and others[17] reported that cementation of zirconia crowns with glass ionomer cement did not cause a significant increase in the vertical marginal discrepancy (3-8 μm) for three different systems. In contrast, in the current work, there was a statistically significant difference in the mean marginal gaps (37 μm) between precementation and postcementation for all cements. However, the two studies differ in methodology: Gonzalo and others used standardized stainless steel abutments, whereas the current study used natural teeth.

Martínez-Rus and others[22] studied the effect of two luting cements, resin and glass ionomer cement, on marginal openings among four all-ceramic systems. The AMD of the crowns was measured before and after cementation with scanning electronic microscopy. In accordance with the current study, they observed statistically significant differences in the mean marginal openings before and after cementation. The resin cement resulted in larger marginal discrepancies compared with those of the glass ionomer cement. Zirconia copings (Y-TZP) produced a more favorable marginal fit than CAD-CAM and pressed lithium disilicate copings cemented with resin cement on implant abutments.[38] Similar to the current study, the difference in the marginal discrepancy of the Y-TZP copings between precementation and postcementation was 46 μm.[38] In summary, based on the findings of this *in vitro* study, self-adhesive resin cements with 50-μm virtual cement space cause only slight elevation of the crown within the limits of clinical acceptability.

However, marginal leakage postcementation depends not only on the amount of cement exposed but also on the solubility and adhesive properties of the cement. Accordingly, Gu and others [39] demonstrated that the adhesive composite resin luting system resulted in the least leakage when zinc-phosphate cement, compomer cement, and adhesive composite resin cement were evaluated for marginal discrepancies and leakage of all-ceramic crowns.

Zirconia crown copings can be luted with conventional cements (zinc phosphate cement and glass ionomer) but attain retention only in favorable tooth preparations by mechanical interlocking of the luting agent in the irregularities present on the surfaces of both the restoration and the tooth. However, the lack of adhesion and the absence of a chemical bond to the tooth structure result in poor retention compared with the SARCs.[40,41] The second part of our study aimed to evaluate the retentive strength of the Lava zirconia crown copings after cementation with three SARCs and resin cement with self-etch primer as a control after nine months of aging in 100% humidity. Our null hypothesis for this study was rejected because the mean coping removal stress was significantly different among the four groups. The highest mean dislodgment stresses were observed for SC2 and GCA (approximately 1.4 MPa and 1.2 MPa, respectively), and the lowest were observed for PAN and RXU200 (approximately 0.7 MPa and 0.5 MPa, respectively). The relatively high SD reflects the variability between the teeth and is common with the results of experiments performed with natural teeth,[9,11,12] but a significant difference could be detected. These removal stress values were appreciably lower than those reported in other studies evaluating the retentive strength of identical cements[9,12,42,43] for luting zirconia crowns, which reported values of 4.8-9.7 MPa. These differences might be attributable to the surface treatment method and aging. The manufacturers of PAN and RXU200 recommend sandblasting the inner surface of the crown before cementation, whereas the manufacturers of SC2 and GCA do not require this step. For the purpose of standardization, we can either include or omit that step for all of the cements. The issue of sandblasting the intaglio of the crown is controversial because it has the potential to create surface microcracks that can decrease the strength of the zirconia.[41,44] We therefore decided to omit this step for all of the cements for the purpose of standardization. However, previous studies that have reported much higher retentive values treated the copings by either airborne-particle abrasion with 50- μm aluminum oxide (Al_2O_3),[9,43] sandblasting with 100-μm alumina,[42] or tribochemical coating with silica.[12,42] The value of grit-blasting the zirconia surface with 50-μm Al_2O_3 as a simple and effective treatment for improving retention compared with no treatment was recently reported by Şanlı and others.[44] Moreover, Inokoshi and others[45] conducted a meta-analysis of bonding effectiveness to zirconia and reported a trend of higher bonding effectiveness when zirconia was pretreated by either Al_2O_3 sandblasting or tribochemical silica coating, particularly compared with studies in which zirconia underwent no mechanical pretreatment. However, when deciding to improve mechanical retention by grit-blasting, the particle size must be limited to minimize subsurface damage and the risk of cracking the zirconia substrate.[44]

In our study, the cemented copings underwent 100% humidity at 37°C for 270 days and were subsequently thermal cycled between water temperatures of 5°C and 55°C for 10,000 cycles. In studies reporting much higher retentive values, the aging processes involved much shorter times of 24 hours,[9] one week,[12] or 14 days.[42,43]

A few recent studies have reported results similar to our results after prolonged aging. De Sá Barbosa and others[46] evaluated the microshear bond strength of four SARCs to yttria-stabilized tetragonal zirconia surfaces after water storage for 24 hours or one year. The latter period significantly decreased the microshear bond strengths to zirconia for all cements by 53%-91%. Da Silva and others[47] compared the bond stability of RelyX adhesive resin cement (conventional) and RelyX Unicem (self-adhesive) resin cement with a yttria-stabilized tetragonal polycrystalline zirconia (ceramic submitted to two surface treatments after six months of aging in water). Irrespective of surface treatments, the self-adhesive resin cement was not able to maintain the bond to Y-TZP ceramic after six months of aging in water, with a decrease in retentive values of 43%-93%.[47] Of note, the RelyX SARC family exhibited the highest extent of degradation, >90%.[46,47] Degradation of RelyX Unicem after aging was also reported by Perdigão and others[48] and de Melo and others.[49] Thus, it is quite reasonable that the severe aging processes in the current study influenced the SARCs as well as the control and caused their degradation and hydrolysis. This conclusion was reinforced by a recent study by our group in which the retentive strength of zirconia crowns was tested using an identical methodology.[50] The crowns were cemented with RXU200 without sandblasting and tested after only 30 days. The retentive values obtained were higher, 2.28 MPa, because no aging over a prolonged period was performed.[50] Examination of the failure mode revealed that the main mode of failure for all cementation groups was mixed mode. However, the groups with the lowest retentive values (RXU200 and PAN) exhibited dominance of surfaces with failures between the cement and crown, whereas the groups with the highest retentive values (GCA and SC2) exhibited dominance of surfaces with failures between the cement and dentin. These observations suggest that, as per the manufacturers' recommendations for RXU200 and PAN, it is crucial to sandblast the intaglio surfaces of the Y-TZP crowns to avoid adhesive cement-crown failures. An appreciable improvement in the adhesion of RXU200 to zirconia by surface grit blasting was recently reported,[44,47] whereas adhesive cement-crown failure is mainly anticipated without grit-blasting.[50] An alternative option to increase the retention between RXU200 and the zirconia substrate is the use of zirconia primers.[51]

It is anticipated that greater incomplete seating postcementation will reduce retention, based on studies of gold castings cemented by zinc phosphate cement showing a reduction of 19%-32% in crown retention due to incomplete seating.[52] The results of the current study support our second null hypothesis, given that no relationship was observed between retention and AMG. The before and after AMG values, as well as the differences between them, gave low negative nonsignificant Pearson correlation coefficients with retention. Although the negative signs indicate that an inverse relationship exists, the low and nonsignificant correlations suggest a weak relationship. With the current CAD-CAM crowns, the predictable preplanned 50-μm virtual spacing provided sufficient cementation space for the excess cement. By contrast, the manually provided 20- to 40-μm die spacer for cast gold crowns was unpredictable.[37]

CONCLUSIONS

We have shown that AMGs of LAVA Y-TZP crowns as fabricated (35 μm) and after cementation by self-adhesive resin cement (72 μm) were within the limits of clinical acceptability of 120 μm. This limit was traditionally set for cast gold copings but is also widely accepted for all-ceramic crowns. Self-adhesive resin cements and resin cement with self-etch primer are anticipated to cause minimal crown elevation postcementation provided that a virtual spacer of 50-μm thickness 0.5 mm short of the margins is set. In contrast, the retention strength of these Lava Y-TZP crowns after severe aging conditions yielded unsatisfactory values (<1.4 MPa), which greatly differed between the cements. The lowest values (<0.74 MPa) were found for RXU200 and PAN, which exhibited mainly adhesive cement-crown failures. These values could have been improved by sandblasting the intaglio surfaces of the Y-TZP crowns. No relationships were found between retention and AMG.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Tel Aviv University. The approval code for this study is 13.11.2015.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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