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Effect of Two Self-Adhesive Cements on Marginal Adaptation and Strength of Esthetic Ceramic CAD/CAM Molar Crowns

Werner Mörmann, Dr med dent,[1] Daniel Wolf, Dr med dent,[2] Andreas Ender, Dr med dent,[2] Andreas Bindl, Dr med dent,[3] Till Göhring, Dr med dent,[3] & Thomas Attin, Dr med dent[4]

[1] Professor and Director, Division of Computer Restorations, Department of Preventive Dentistry, Periodontology and Cariology, Center for Dental and Oral Medicine, University of Zurich, Switzerland
[2] Research Associate, Division of Computer Restorations, Department of Preventive Dentistry, Periodontology and Cariology, Center for Dental and Oral Medicine, University of Zurich, Switzerland
[3] Senior Research Associate, Division of Computer Restorations, Department of Preventive Dentistry, Periodontology and Cariology, Center for Dental and Oral Medicine, University of Zurich, Switzerland
[4] Professor and Chairman, Department of Preventive Dentistry, Periodontology and Cariology, Center for Dental and Oral Medicine, University of Zurich, Switzerland

Keywords
Self-adhesive cements; CAD/CAM molar crowns; esthetic ceramic; marginal adaptation; crown strength; thermo-mechanical fatigue; dentinal fluid pressure.

Correspondence
Werner H Mörmann, Division of Computer Restorations, Department of Preventive Dentistry, Periodontology and Cariology, Center for Dental and Oral Medicine, University of Zurich, Plattenstrasse 11, CH-8032 Zurich, Switzerland.
E-mail: werner.moermann@zzmk.uzh.ch

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Abstract

Purpose: This study evaluated the effects of adhesive cements on marginal adaptation and fracture resistance of ceramic molar crowns.
Materials and Methods: Seventy-five extracted maxillary molars were selected. The occlusal morphology of 15 molars (control) was scanned and transferred to the crowns in the test groups by CAD/CAM. Sixty molars received full-coverage crown preparations with 6-degree axial taper, 1.0-mm shoulder, and 2.0-mm occlusal reduction. They were assigned to four groups, and pulpal pressure was simulated. The 15 crowns in each test group were seated with resin-based self-adhesive cements, Rely-X (RX) and Multilink (MS), one multistep bonded adhesive luting composite resin, Variolink (VL), and glass-ionomer cement, Ketac Cem (KC). Test and control molars were subjected to thermal and mechanical fatigue stress (TMS: 12,000 × 5°C to 50°C; 2.4 million × 49 N) for 18 days in a masticator. Marginal adaptation ["continuous margin%" (CM%)] of the crowns was determined by scanning electron microscopy (200×). Finally, molars were occlusally loaded until fracture in a testing machine, and fracture load (N) was recorded. Marginal adaptation and strength data were statistically analyzed.
Results: TMS significantly ($p < 0.001$) reduced CM% in all groups. After TMS, CM% at the cement-dentin interface was significantly ($p < 0.001$) higher for RX than for all other cements. At the crown-cement interface both self-adhesive cements MS and RX had significantly better CM% than VL ($p < 0.05$) and KC ($p < 0.001$). Fracture resistance of natural untreated molars was significantly ($p < 0.001$) higher than that of experimental crowns. Fracture resistance of RX cemented crowns was significantly ($p < 0.05$) higher than that of other crowns. Occlusal morphology significantly influenced fracture resistance ($p < 0.05$).
Conclusions: Self-adhesive cement RX offers a valid alternative to multistep resin-based luting composite with respect to marginal adaptation to dentin and fracture resistance. The latter is also influenced by occlusal morphology, necessitating careful monitoring of occlusal contacts.

In-office chairside CAD/CAM offers the possibility of fabricating esthetic ceramic molar crowns during one visit using feldspathic CAD/CAM machinable block ceramic or leucite-reinforced glass-ceramic.[1] Both materials are categorized as filler particle-containing glass-matrix esthetic ceramics.[2] The flexural strength of feldspathic ceramic after CAD/CAM machining is between 103 and 127 MPa,[3,4] and 121 and 141 MPa in our own laboratories (three-point bending), characterizing it as a machinable but relatively weak ceramic.[5] CAD/CAM offers diverse options to generate and replicate natural occlusal morphology.[6-8] Static load-to-fracture studies of esthetic ceramic CAD/CAM molar crowns have shown significant strengthening of esthetic ceramic molar crowns by adhesive cementation with multistep bonded luting composite resins versus nonadhesive cementation.[9-11] For adhesive cementation, loads to failure of 3132 N were recorded, while crowns seated with nonadhesive cement reached only 1680 N in a static load study.[9] In another study, after thermomechanical fatigue, loads to failure of

775 N for adhesive cementation versus 571 N with conventional cement were observed.[11] Experimental strengthening mechanism led to high loads to failure, following bonding of weak ceramic with rigid composite resins with a high modulus of elasticity.[12,13]

Clinical studies on the long-term success of all-ceramic posterior restorations show increased longevity for crowns cemented with multistep adhesive bonding/resin-based luting agents.[14] Resin-bonded esthetic ceramic premolar and molar CAD/CAM crowns were reported to show 97% and 94.6% survival up to 7 years, respectively.[15] Consequently, the quality of the marginal interfacial bond as provided by multistep dentin-enamel adhesives in combination with resin-based luting cements[16-20] appeared to primarily determine the longevity of posterior esthetic ceramic CAD/CAM restorations.

The practical need to simplify application procedures of adhesive cementation of posterior restorations led to the development of self-adhesive cements.[21] Glass ionomer, as a nonresin-based cement, originally was the only self-adhesive material,[21] but glass ionomers provide low support to all-ceramic crowns,[22] and the material fails internally rather than by debonding from the tooth surface.[21] Self-adhesive resin-based cements, however, show favorable results of marginal adaptation[23] and mechanical support[24,25] of all-ceramic posterior crowns. The question arises whether self-adhesive resin-based cements are able to provide adequate marginal adaptation and strength for esthetic ceramic CAD/CAM crowns with their particular physical properties.[26-34] We hypothesized that there would be no difference between resin-bonded crowns and those cemented with self-adhesive resin-based cement with regard to marginal adaptation and strength of ceramic CAD/CAM crowns after extensive thermomechanical fatigue stress with dentinal liquid pressure maintained.

In recent studies testing the strength of ceramic restorations, occlusal morphology was standardized to minimize variance of measurements by uncontrolled variation of the occlusal morphology.[3,9-11,22,23,25] Recent developments in CAD/CAM technology now allow scanning of the natural occlusal morphology, for example, of a maxillary molar, and exact replication in a newly designed esthetic ceramic crown.[8] Hence, occlusal morphologies of natural molars can be transferred to ceramic test crowns cemented on molar tooth preparations of similar size. If loaded under the same conditions, the influence of naturally varying occlusal morphology on the strength of ceramic crowns may be assessed. We hypothesized that fracture resistance would be influenced by occlusal morphology. Although this seems obvious, evidence on this topic has not yet been presented in a controlled study.

The objective of this study was to evaluate the effects of self-adhesive cementation on marginal adaptation and fracture resistance of esthetic ceramic CAD/CAM-generated crowns as well as to assess the influence of occlusal morphology on strength.

Materials and methods

Seventy-five extracted maxillary human molars were selected from the department's collection of extracted teeth according to size with mesiodistal as well as buccolingual dimensions in a range of 10.3 ± 0.6 mm. They were divided into five groups (four test and one control group, $n = 15$).

The roots of the molars were coated with a 0.3-mm layer of poly(vinyl siloxane) (President light, surface activated, Coltène, Altstätten, Switzerland) to simulate the periodontal ligament as described in an earlier study.[35] They were fixed in the center of specimen holders with a chemically polymerizing resin (Paladur, Kulzer, Wehrheim, Germany). To enable the simulation of dentinal fluid pressure during preparation, cementation and thermomechanical stress (TMS) intrapulpal pressure of about 25 mmHg was established in the molars of all test groups, as described by Krejci et al.[36]

The 60 test molars were prepared with 6-degree axial taper, 1.0-mm shoulder, and 2.0-mm occlusal reduction. The preparation resulted in a stump height of 5 to 6 mm and was performed using cylindrical 80-μm grain-size diamond burs (FG 8614, Intensiv, Grancia, Switzerland) and 25-μm finishing burs (FG 3614, Intensiv) under continuous cooling with water spray. Additional finishing was done with Sof-Lex disks (3M ESPE, Rüschlikon, Switzerland). The preparation surface area of all preparations was scanned and measured as described earlier[37] to verify similarity of the preparations, and amounted to 160 ± 18 mm^2. The preparations were scanned and restored with CAD/CAM crowns. CAD/CAM hardware and software used in this study are listed in Table 1.

The optoelectronic intraoral camera of the acquisition unit was used to scan the occlusal morphology of the control molars. For scanning, the camera was mounted on a tripod and positioned over the molars fixed with specimen holders in a support and coated with scanspray (Scan'Spray, Dentaco, Bad Homburg, Germany) as described earlier.[38] The scans of the occlusal morphology of the 15 control molars were used for the CAD design and fabrication of analogous crowns in each of the four test groups. This served to group the 15 crowns in each test group according to the occlusal morphology of one corresponding control molar (Fig 1).

On the monitor of the acquisition and design unit, commands were entered using track ball and cursor clicking of the respective windows and icons following the design steps as described previously.[8] Minimum occlusal thickness in the main fissure was set to 1 mm. The form-grinding process was kept the same throughout the study using the same hardware, software, parameter settings, ceramic, diamond burs, and milling mode. The set of diamond burs and cooling water plus grinding agent were changed after form grinding of 12 crowns each.

The cements, adhesive systems, and ceramic conditioning materials used are presented in Table 2.

Physical properties of the restorative materials used in this study as retrieved from the literature[3,4,26-33] and from technical data sheets of manufacturers are presented in Table 3.

The cements (Table 2) were applied to the internal surface of the crown, and the crown was positioned on the preparation. Gross excess material was removed with a spatula, and crowns cemented with resin-based cements were light cured for 40 seconds each from the occlusal, buccal, and lingual sides. When cemented with glass-ionomer cement, the crowns were held in position for 3 minutes with finger pressure, and excess material was removed. Margins were finished and polished with flexible disks (Sof-Lex). Immediately after polishing, one mesial

Table 1 CAD/CAM fabrication of crowns: machining hardware, software

Instrument/material	Hardware	Software
CAD/CAM	Cerec 3D - Acquisition unit serial no. 01394 - Milling unit serial no. 01307 Bensheim, Germany	Cerec 3D version R2400 restoration: "crown" design mode: "replication" Sirona
Burs/parameters/settings	- Step bur ø 1.0 mm, D64 μm diamond coating, no. 54 66 193	- Margin width parameter set to: 10 μm
	- Pointed bur ø 1.6 mm, D64 μm diamond coating no. 58 55 734	- Spacer width parameter set to: 20 μm
Ceramic	Esthetic-ceramic CAD/CAM blocks, Vitablocs Mark II, size I14, lot 7535 and 7542 Vita Zahnfabrik	Standard milling mode
Grinding agent	Dentatec, Sirona, 70 ml per tank fill	—

or distal section of the crown margin was randomly selected for margin analysis, and the chosen site marked at the specimen holder to be identified after testing. An impression was made of this margin section with a poly(vinyl siloxane) impression material (President light body), and replicas prepared for quantitative margin analysis in a scanning electron microscope (SEM). Thereafter, molars were stored in tap water at room temperature for at least 2 weeks before entering the thermomechanical cycle.

Test and control molars were entered into a computer-controlled masticator[36,39] and subjected to thermomechanical cyclical stress under water for 18 days. Thermal and mechanical stress were applied simultaneously. Going through 12,000 thermal cycles, temperature alternated between 5°C and 50°C, the dwell time of the low and high temperature was 120 seconds each, and the water exchange took 10 seconds. Mechanical stress was exerted through 2.4 million loads with a maximum load force of 49 ± 0.7 N each, a load frequency of 1.7 Hz, and load cycle duration of 0.6 seconds.

Maxillary molar cusps were mounted as antagonists and occluded with the anatomical surface of the central fossae of natural and restored molars. The rubber bumper support[39] of the test crown tooth and its artificial periodontal ligament[35] allowed a certain degree of jiggling of the tooth when loaded. The dentinal fluid simulation was maintained during cementation and the entire TMS period.[36] After the stress period, replicas were made again from the same margin section for SEM evaluation. They were compared with the replicas made initially using a semi-quantitative margin analysis at 200× magnification by SEM. Percentages of "continuous margin," that is, no visible loss of adhesion or fracture of cement or dentin, were measured for the dentin-cement and cement-dentin interfaces.[36]

Finally, natural and restored molars were mounted in a universal testing machine (Zwick Z010, Ulm, Germany). Four layers of a teflon foil (0.2-mm thickness, no. 540, Angst & Pfister, Zurich, Switzerland) were placed in between the crown, and a load transfer steel ball (Ø 9 mm) to avoid load peaks in the contact area. Via the Teflon foil, the steel ball made contact with three internal cusp slopes of the maxillary control and crowned molars. Loading was done with a crosshead speed of 0.5 mm/min until fracture. The load force (N) was recorded on a digital display, and at fracture the maximum load force (N) was displayed and entered into Excel (Microsoft Office Mac 04, Redmond, WA) tables. All continuous margin (CM%) and fracture load data were entered into the StatView Program 4.5 (Brain Power, Calabasas, CA) and are presented here as box-plot diagrams. One-way analysis of variance (ANOVA) and Scheffé tests were used for analysis of margin adaptation and overall fracture load. Kruskal-Wallis test was used to analyze the fracture load data with regard to the influence of occlusal morphology on crown strength by choosing occlusal morphology as a grouping variable. Paired *t*-test was used to compare

Figure 1 Grouping of test crowns according to copied occlusal morphology of natural control tooth. Natural control molar tooth (left) and four test molars of similar size crowned with ceramic CAD/CAM crowns each with the same replicated occlusal morphology of the control tooth. Metal tubes mounted for the application of intrapulpal fluid pressure are visible.

Table 2 Type of cements, dentin conditioning, ceramic conditioning, and light curing

Cements	Type	Dentin conditioning	Ceramic conditioning	Light curing[a]
Variolink Ultra (VL) Base A3, lot G06716 Ivoclar Vivadent (Schaan, Liechtenstein)	Light-activated resin cement	Syntac Classic SC-Primer, lot E09369[b] 30-second application SC-adhesive, lot E08386[b] 30-second application Heliobond, lot E10061[b] 30-second penetration 40-second light cured[a]	Ceramics etch 4.9% hydrofluoric acid gel, 30 seconds (Vita Zahnfabrik) Monobond S, Silane agent, lot H08177[b] 60 seconds Heliobond lot E10061[b]	3 × 40 seconds occlusal, buccal, and lingual
Multilink Sprint (MS) transparent, lot J11950 Ivoclar Vivadent	Self-adhesive universal dual-cure resin cement	No	Ceramics etch 4.9% hydrofluoric acid gel, 30 seconds (Vita Zahnfabrik)	
RelyX Unicem (RX) A2, lot 278278 3M ESPE (Minneapolis, MN)	Self-adhesive universal dual-cure resin cement	No	Monobond S, Silane agent, lot H08177 60 seconds	
Ketac Cem (KC) A2, lot 216105 3M ESPE	Glass-ionomer cement	No	No	No

[a]LED light-curing unit 1100 mW/cm^2 (Bluephase).
[b] Ivoclar Vivadent.

crown strengths between cementation test groups. The level of significance was set to 5%.[40]

Results

The results of the continuous margin SEM analysis are visualized as an overview in a box-plot diagram (Fig 2), and detailed information such as means, standard deviation, and statistical significance are presented in Table 4. All control and crowned molars survived TMS. No loss of retention or visible fracture was observed, and all crowned molars were used for marginal adaptation analysis and final load-to-fracture testing. TMS significantly ($p < 0.001$) reduced marginal adaptation at both the crown-cement and cement-dentin interfaces in all groups.

After TMS, margin quality provided by multistep adhesive bonding/resin-based luting composite, Variolink (VL), and self-adhesive resin-based cement, Multilink (MS), at the cement-dentin interface was relatively low with a high standard deviation. Self-adhesive cement, Rely-X (RX), provided significantly ($p < 0.001$) better marginal adaptation at the cement-dentin interface after TMS than all other cements (Fig 2, Table 4). At the crown-cement interface of adhesively cemented crowns, marginal adaptation stayed relatively high after TMS, but glass-ionomer cement, Ketac Cem (KC), CM% dropped by 30%.

As the result of the load-to-fracture test, the control natural molars (NM) showed bulk enamel sections sheared off from the dentinal subsurface (Fig 3) or chipping of enamel at the external surface of one of the cusps. None of the natural molars had fracture through dentin or through the entire tooth. Crowns broke into two to four fragments and chips. Typical fracture examples are shown in Figure 3.

Fractures originated either in the thinnest crown part or in a load transfer contact. Fracture of the adhesively (VL) or self-adhesively (RX, MS) cemented crowns left approximately half of the crown still adhering to the dentin stump (Fig 3). On the VL, RX, and MS crown fragments, the adhesive cement still adhered to the ceramic without exception. In the VL and RX groups, there were three specimens each showing fractures right through the prepared tooth and continuing through the root (RX) (Fig 3). One RX-cemented crown showed chipping

Table 3 Physical properties as retrieved from dental literature[3,4,26–33] and from data sheets of the manufacturers

Material	Flexural strength (MPa)	Modulus of elasticity (GPa)	Compressive strength (MPa)	Coefficient of thermal exp (10^{-6} K^{-1})
Enamel	60 to 90[26]	41[33]	400[27]	10[33]
Dentin	245 to 280[26]	18.6[33]	297[27]	11.4[33]
Vitablocs Mark II	103[3,4](machined)	45[a]	157 ± 20[32]	8.8 ± 0.02[31]
Variolink Ultra, base	125[b](light cured)	9[b](light cured)	300[b] (light cured)	48[b]
Multilink Sprint	90[b](light cured)	8.1[b](light cured)	200[b](light cured)	53[b]
RelyX Unicem	63[c]	11.2 to 13.6[30]	240[c](light cured)	No data available
Ketac Cem	11.6(24 hours)[28]	6.3[29]	80 (24 hours)[28]	35[33]

Technical data sheets: [a]Vita Zahnfabrik, [b]Ivoclar Vivadent, and [c]3M ESPE.

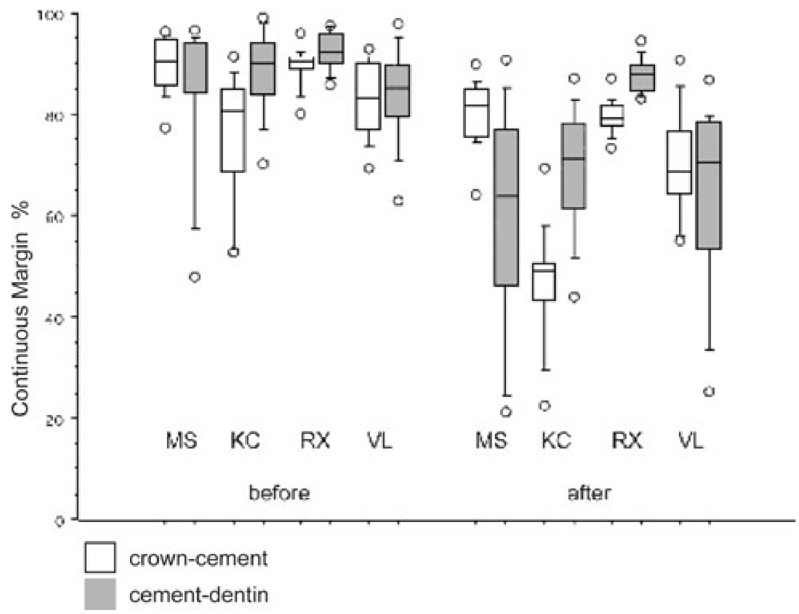

Figure 2 Semiquantitative SEM evaluation of marginal adaptation, "continuous margin%" of crown-cement and cement-dentin interfaces before and after thermomechanical stress and dentin fluid pressure of self-adhesive cements MS and RX, glass-ionomer cement KC, and functional adhesive bonding/resin-based luting composite system VL.

of the ceramic, while the dentin was not exposed. Fracture parts of crowns cemented with glass ionomer (KC) all came off while the cement was still adhering to the dentin but showed crazing over the entire surface (Fig 3). We never observed KC adhering to the ceramic after fracture.

The mean fracture load of the natural control molars (2156 ± 944 N) was significantly higher ($p < 0.001$) than the strongest crowns cemented with self-adhesive cement RX (1434 ± 450 N) and than any of the other crowned molars cemented with cements VL (1087 ± 292 N), MS (1042 ± 315 N), and KC (1029 ± 308 N) (Fig 4). Crowns cemented with self-adhesive cement RX were significantly stronger than the crowns cemented with self-adhesive cement MS ($p < 0.01$), the conventional resin-based luting cement with a multistep adhesive bonding system VL ($p < 0.05$) and also stronger than glass-ionomer cement KC ($P < 0.001$).

Significant differences ($p < 0.05$) between the strength of test crowns with varying individual occlusal morphology indicated influence of the occlusal morphology on the strength of the esthetic ceramic CAD/CAM crowns independent of the type of cement or adhesive luting agent used.

Table 4. Marginal adaptation expressed as "continuous margin %," means and standard deviations (N = 15) before and after thermomechanical stress (TMS)

Marginal adaptation (continuous margin %)				
Cement	Interface		Before TMS	After TMS
VL	Dentin		83 ± 10	65 ± 19***
VL		Crown	83 ± 7	71 ± 10
RX	Dentin		92 ± 3	88 ± 3
RX		Crown	***89 ± 4	80 ± 3
MS	Dentin		86 ± 14	60 ± 20***
MS		Crown	***90 ± 5	80 ± 6
KC	Dentin		88 ± 8	70 ± 13***
KC		Crown	76 ± 12	47 ± 10

*$p < 0.05$; ***$p < 0.001$. The p-values according to Scheffé test, significance level 5%. The significant differences at cement-crown interfaces after TMS for MS/KC, MS/VL, RX/KC, VL/KC ($p < 0.001$), and for RX/VL ($p < 0.05$) are not indicated in the table.

Discussion

This study aimed at challenging marginal adaptation to dentin more than other studies[20,22–25,41] by applying extensive thermomechanical fatigue stress (2.4 million loads) plus maintaining dentinal liquid pressure during cementation and TMS.

Other than in this study, marginal adaptation of ceramic crowns to dentin after TMS (1.2 million loads) and without dentin fluid pressure did not cause a statistically significant difference between self-adhesive RX and adhesive bonding with VL.[23] The different number of loads, the dentinal fluid pressure, or both factors may have been responsible for the difference between the results of the two studies. Dentinal fluid pressure is considered as a relevant parameter providing quasi-clinical conditions for in vitro testing of dentin adhesion.[36,42,43] The influence of dentinal fluid was specific to the adhesive agents.[36] In particular, the functional adhesive used in this study (VL) showed a tendency to deterioration of the margins, while in another study it was not influenced.[36] Contemporary self-etching dentin-bonding agents, for example, are susceptible to water permeation induced by pulpal pressure,[43] while self-adhesive cement RX has a different bonding mechanism.[44]

These results suggest that the bonding mechanism of RX was better able to withstand long-lasting TMS and presence of dentinal fluid than multistep adhesive bonding and resin-based luting composite VL, rejecting the null hypothesis that marginal adaptation would be the same for RX and VL. Reports

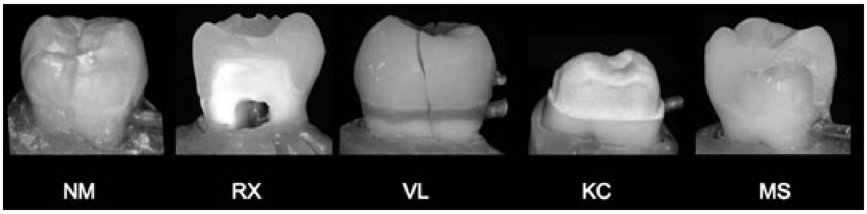

Figure 3 Typical breakage examples of natural uncrowned control tooth NM and fractured crowns cemented with self-adhesive cements RX and MS, with multistep adhesive resin cement VL and glass-ionomer cement KC after thermomechanical stress and loading to fracture.

of low microleakage of RX-cemented crowns compared to standard resin-cemented crowns[45] and of high microleakage of VL-cemented all-ceramic crowns in dentin[19] may be interpreted in the same sense.

As in other studies,[23,41] we considered the multistep adhesive bonding VL luting system as a standard for luting ceramic restorations; however, the low performance of VL in this study may be based on the very superficial interaction of the adhesive with the dentinal surface, the adhesion deteriorating with time, and insufficiently resisting debonding in the long term.[21] Similar bond strength of VL and RX resulting from shear bond testing after thermocycling[41] may not be comparable, because these studies lack dentinal liquid pressure and mechanical loading. The relatively low marginal adaptation of the self-adhesive cement MS to dentin indicates a high sensitivity of MS to the test conditions. At present, there are no reports available on the bonding capacity of MS to dentin and its performance. According to the manufacturer's data sheet, hydrophilic monomers penetrate and modify the smear layer, and phosphoric acid methacrylates provide chemical bond to the dentinal calcium. These mechanisms may have been counteracted by dentinal fluid, and polymerization may have been impeded.[36,43]

Both self-adhesive cements MS and RX showed excellent adhesion to the esthetic ceramic of the crowns. The bond of resin-based cements to esthetic ceramic is provided through

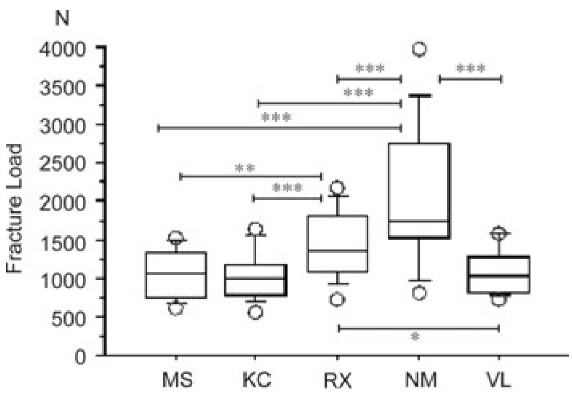

Figure 4 Fracture load (N) after thermomechanical stress of natural untreated maxillary molars (NM) and ceramic CAD/CAM crowns cemented with self-adhesive cements MS and RX, glass-ionomer cement KC, and multistep adhesive bonding system VL. Significant differences between natural NM and crowned molars (***$p < 0.001$, Scheffé test, significance level 5%) are indicated as well as significant differences between RX and other crowns: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$ (Kruskal-Wallis, paired *t*-test).

conditioning with hydrofluoric acid and silanization.[4,46,47] At the cement-crown interface, the CM% before and after TMS was highest for both self-adhesive cements MS and RX, followed by VL with lower, and KC with the significantly lowest margin adaptation, indicating that KC as a classical glass-ionomer cement did not provide durable marginal adaptation and bond to esthetic ceramic from the beginning. No KC adhering to the ceramic after fracture was seen in this study. It did not debond from the tooth surface but seemed to fail internally, confirming previous reports.[21]

Two types of mechanical stress were applied in this study, namely the low cyclical load aiming at weakening the ceramic by fatigue and the excessive high stress caused by the final static load-to-fracture test. The cyclical loading with 49 N can be categorized at the lower end of the range of reported average masticatory loads of 5 to 364 N, with static mean failure load of 684 N or mean 1-year cyclic failure load of 275 N.[48] In fact, no visible external damage was observed in the occlusal contact area of the crowns after TMS. The occlusal internal subsurface of the crowns could not be inspected for any developing cracks at the crown-cement interface as in another study.[10] Consequently, any structural fatigue effect of the experimental conditions on the ceramic could not be assessed. If cracks are present, water can act chemically at crack tips to decrease the strength of ceramic and is likely to be involved in failure of ceramic crowns whether available from the dentin, as possibly in this study, or from transport through dental cements;[48] however, apart from cracks, the loss of marginal adaptation may be interpreted as a weakening of the crown-cement-tooth system with the cement-dentin interface as the critical part.

If adhesion plays a role in the strengthening of esthetic ceramic crowns, which appears well documented experimentally[9–13] and by clinical experience,[14–18] gradual loss of adhesion, whether at the ceramic or the dentin interface, would mean weakening the crown. Visual examination of fracture parts of resin-bonded crowns always showed the resin still adhering to the ceramic, without exception, in this study, matching the authors' clinical experience with fractured esthetic ceramic CAD/CAM crowns.[15] SEM analysis of fracture parts of RX-cemented all-ceramic molar crowns showed that fracture occurred between the hybrid layer and cement.[24] Such detailed analysis was not conducted in this study, so the findings cannot be confirmed on a microstructural basis. In any case, debonding occurs at the dentin-cement interface.

In this study, after thermal and mechanical fatigue stress, the strength of the control molars was significantly higher than any of the cemented crowns, indicating that the sound natural structure of a human molar was still more resistant than the bonded esthetic ceramic crowns as also found in another study.[11] This gives some leeway for further strength improvement of the esthetic-ceramic crown-cement-tooth system. Choosing occlusion as a grouping variable of the fracture load data, the factor "occlusal morphology" had a significant influence on crown strength, rejecting the null hypothesis. Under these conditions, self-adhesive RX-cemented crowns showed significantly higher strength than the other cements tested, rejecting the null hypothesis and doing better than expected.

Conclusions

Self-adhesive cement RX offers a valid alternative to a resin-based composite resin with multistep adhesive bonding, with respect to marginal adaptation to dentin and strength of esthetic ceramic CAD/CAM molar crowns. Occlusal morphology influences the strength of the crowns; careful monitoring of occlusal contacts is recommended.

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