Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns

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Statement of problem. Various machinable materials are currently used with computer-aided design/computer-assisted manufacturing (CAD/CAM) technologies for the chairside fabrication of restorations. However, properties of these new machinable materials, such as fracture load, wear, marginal deterioration, and color stability, should be investigated in vitro under replicated clinical conditions prior to time-consuming clinical studies.

Purpose. This study investigated the effect of cyclic loading fatigue and different luting agents under wet conditions on the fracture load of CAD/CAM machined composite resin and all-ceramic crowns.

Materials and methods. Ninety-six intact human maxillary premolars were prepared for composite resin and all-ceramic crowns with the following preparation criteria: 6-degree axial taper, 1.5-mm shoulder finish line placed 0.5 mm occlusal to the cemento-enamel junction, 1.5-mm axial reduction, 2-mm occlusal reduction, and 5-mm occluso-gingival height. Sixteen unprepared premolars served as controls. Forty-eight all-ceramic crowns (Vita Mark II) and 48 millable composite resin crowns (MZ100 Block) were fabricated using a CAD/CAM system (Cerec 3). Three luting agents—RelyX ARC (RX), GC Fuji CEM (FC), and zinc phosphate cement (ZP)—were used for cementation (n=16). After 1-week storage in water, half of the specimens (n=8) in each subgroup were cyclically loaded and thermal cycled under wet conditions for 600,000 masticatory cycles and 3500 thermal cycles (58°C/4°C; dwell time, 60 seconds) in a masticatory simulator; the other half (n=8) were fractured without cyclic loading. All specimens were loaded in a universal testing machine with a compressive load (N) applied along the long axis of the specimen at a crosshead speed of 1 mm/min until fracture. Fracture loads (N) were recorded for each specimen. Three-way analysis of variance was used to detect the effects of the experimental factors (crown material, luting agent, and loading conditions) on the fracture load. The comparison with the unprepared natural teeth as controls was done by means of t tests (α=.05).

Results. Analysis of variance revealed a statistically significant influence of the luting agent and the cyclic loading ($P<.001$), whereas the crown material had no significant influence. Cyclic loading fatigue significantly decreased the mean fracture load of test groups independent of the 3 luting agents used: MZ100/ZP, 827.1 to 552.5 N; MZ100/FC, 914.7 to 706.2 N; MZ100/RX, 955.9 to 724.4 N; Vita/ZP, 772.3 to 571.5 N; Vita/FC, 923.6 to 721.1 N; and Vita/RX, 929.1 to 752.7 N. However, there was no significant difference in the mean fracture load of control specimens before and after cyclic loading (1140.1 N and 1066.2 N, respectively). Adhesive luting agents RelyX ARC and GC Fuji CEM increased fracture load significantly compared to zinc phosphate cement.

Conclusions. Cyclic loading fatigue significantly reduced the fracture loads of composite resin and all-ceramic crowns, whereas adhesive cementation significantly increased the fracture loads. (J Prosthet Dent 2006;95: 117-23.)

CLINICAL IMPLICATIONS

Regarding fracture loads, CAD/CAM crowns fabricated from millable composite resin blocks are an alternative to all-ceramic crowns fabricated from conventional feldspathic machinable ceramic (Vita Mark II). However, other important factors, such as wear and color stability, must be evaluated before composite resin crowns can be recommended clinically.

In spite of the advantages of all-ceramic restorations, including esthetic appearance, biocompatibility, and durability, such materials present with some disadvantages.[1,2] The potential of brittle catastrophic fracture and abrasive wear of the opposing natural teeth except with the use of current low fusing ceramic are

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Table I. Materials used in study

Material	Composition	Lot/Batch No.	Manufacturer
Vita Mark II	Conventional feldspathic ceramic with fine-grain particle size	67975	VITA Zahnfabrik, Bad Sackingen, Germany
MZ100	Conventional hybrid composite resin, Bisphenol-A-diglycidylether dimethacrylate (BisGMA), triethylene glycol dimethacrylate (TEGDMA), and ultrafine zirconia silica ceramic particles as filler. Particles have spherical shape and average size 0.6 μm	2714	3M ESPE, Seefeld, Germany
RelyX ARC	Bisphenol-A-diglycidylether dimethacrylate (BisGMA), triethylene glycol dimethacrylate (TEGDMA)	3415	3M ESPE
GC FujiCEM	Resin-modified glass-ionomer cement containing HEMA	0010032	GC Corp, Tokyo, Japan
Fast-setting Harvard cement	Zinc phosphate cement	Powder: 2122397027 Liquid: 2121097014	Harvard Dental, Berlin, Germany

considered among these disadvantages.[3-5] Recently, millable composite resin blocks were introduced for use with computer-aided design/computer-assisted manufacturing (CAD/CAM) systems as a substitute for machinable ceramics.[6] When compared to ceramic materials, these composite resin blocks had the lowest material wear rate, the lowest enamel wear rate, and the lowest total wear rate.[6] Fracture resistance of teeth restored using indirect composite resin onlays and inlays was comparable to fracture resistance of teeth restored using ceramic inlays and onlays, with intact teeth serving as control.[7-9] However clinical studies report that longevity of ceramic inlays is better than composite resin inlays.[10,11] Moreover, many disadvantages remain when using direct and indirect composite resin restorations, such as wear, deterioration of surface finish, discoloration, fractures[12,13] and color instability.[14]

Several factors affect the mechanical properties and fracture resistance of new esthetic crowns in vitro: the fabrication technique, the final surface finish of the crowns,[15] the crown/luting agent interface, and the storage conditions before loading until fracture.[1,16-18] Silanization and cementation using adhesive luting resins improved the mechanical properties of definitive restorations compared to nonadhesive cementation.[19-23] In addition, clinical experience suggests that the fracture rate of ceramic restorations decreases if the restorations are bonded with resin-based luting agents rather than cemented using zinc phosphate or conventional glass-ionomer cements.[24] Moreover, clinically cemented restorations are subjected to repeated masticatory forces under dry and wet conditions; therefore, this environment should be replicated during in vitro testing.[25,26] Cyclic loading fatigue significantly decreased the fracture load of several all-ceramic crown systems.[15,27] However, only limited information is available regarding the use of different luting agents and the influence of cyclic fatigue loading on the fracture load of composite resin and all-ceramic CAD/CAM crowns. The purpose of this in vitro study was to evaluate the influence of cyclic loading fatigue under wet conditions with thermal cycling and the use of 3 different luting agents on the fracture load of composite resin and all-ceramic CAD/CAM crown systems.

MATERIAL AND METHODS

One-hundred twelve extracted carious-free and crack-free human maxillary premolars were selected, cleaned of both calculus deposits and soft-tissue remnants, and then stored in 0.1 % thymol solution. Sixteen sound premolars served as an unrestored control group, whereas the other 96 premolars were prepared and divided into 2 groups of 48 specimens for each esthetic material tested. Two machinable materials were used for crown production: a machinable ceramic (Vita Mark II) and a millable composite resin (MZ100 block) (Table I).

Although various machinable materials are available for fabricating metal-free crowns using CAD/CAM systems, such as zirconia ceramic and Lucite-reinforced glass-ceramic blocks, Vita Mark II machinable ceramic and MZ100 millable composite resin materials were chosen because they have the advantages of short milling time and no need for veneering porcelain and chairside polishing, so there is no need for glazing.[1,3,6,12]

Ninety-six premolars were fixed in plastic rings (Plexiglas; Rohn, Darmstadt, Germany) using plaster (Snow white plaster No 2; Kerr, Romulus, Mich). A custom-made paralleling machine was used for tooth preparation using a series of diamond rotary cutting instruments (#6856.310.016 and #8847 KR 314-016; Komet Medical, Lemgo, Germany). The teeth were prepared with the following standardized preparation criteria: 6-degree axial taper, 1.5-mm shoulder finish line placed 0.5 mm occlusal to the cemento-enamel junction (CEJ), 1.5-mm axial reduction, 2-mm occlusal reduction, and 5-mm occluso-gingival height.[1,3,18] After preparation, each plastic ring was sectioned into 2 parts to facilitate removal of plaster under running water to free each premolar for fabrication of the crowns.

A CAD/CAM system[1,3] (Cerec 3; Sirona; Bensheim, Germany) was used for direct fabrication of CAD/CAM composite resin and all-ceramic crowns. The right acrylic resin premolar was removed from a maxillary dentiform (#0623321; KaVo Dental GmbH, Biberach, Germany), and the prepared human premolars were inserted. The prepared teeth were covered with an optical reflection medium (titanium dioxide; Ivoclar Vivadent, Schaan, Liechtenstein), and a digital impression was made with the intraoral camera of the Cerec 3 system. The associated software (version 1.10 R600) was used for designing and milling the crowns.[1] Completion of the CAD/CAM crowns from the 2 materials tested was performed according to manufacturer recommendations. Vita Mark II crowns were finished using porcelain finishing stones (Komet Medical) and then over-glazed according to the following firing program: predrying temperature of 600°C, increase in temperature at the rate of 58°C/min with closing time of 6 minutes, and a final firing temperature of 950°C with holding time of 1 minute. MZ100 crowns were finished using composite resin finishing stones (1112F, 3118F, and 3195FF; KG Sorensen, Sao Paulo, Brazil).

After crown fabrication, the premolars (test and control groups) were fixed in 15-mm-diameter custom-made metal rings. First, the root portion 2 mm below the CEJ was coated with an artificial periodontal membrane made from a gum resin (Anti-Rutsch-Lack; Wenko-Wenselaar GmbH, Hilden, Germany). Each premolar was coronally covered with wax (Modeling wax; Cavex Holland BV, Haarlem, Holland), and then the root was dipped once into the gum resin. After the gum resin dried, the excess at the root tip was removed with a scalpel so that a coating approximately 0.2 mm thick covered the root surface. This coating allowed tooth mobility similar to the physiological mobility of the natural teeth.[1,3] The teeth were then fixed in the metal rings previously described using fast-setting polyester resin (Technovit 4000; Heraeus Kulzer, Wehrheim, Germany).

Each crown system was divided into 3 subgroups (n=16) to be luted with the following 3 luting agents: RelyX ARC (group RX), GC Fuji CEM (group FC), and zinc phosphate cement (group ZP) (Table I). The intaglio surfaces of Vita Mark II crowns were etched using 4.9% hydrofluoric acid (HF) etching gel (Ceram Total Etch; Ivoclar Vivadent) for 1 minute, as etching alone is a source of micromechanical retention that improves bonding with zinc phosphate cement.[19] Because HF acid etching may also weaken the crowns to some degree, this variable was included for all test groups. Moreover, since resin-modified glass-ionomer cement contains 2-hydroxyethyl methacrylate (HEMA), etching and silanization improves bonding of resin-modified glass-ionomer cement to the crowns.[21]

The intaglio surfaces of the MZ100 crowns were treated with airborne-particle abrasion using 50-μm aluminum oxide particles at 0.20-MPa pressure. Both ceramic and composite resin crowns were thoroughly cleaned with water spray for 60 seconds, followed by ultrasonic cleaning in distilled water for another 60 seconds. Oil-free compressed air was used for drying the intaglio surfaces. A silane coupling agent (Rely X ceramic primer; 3M ESPE, Seefeld, Germany) was immediately applied to the intaglio surface of both crown systems to be luted using adhesive resin and resin-modified glass-ionomer cements.

In group RX, RelyX ARC, a dual-polymerizing resin cement in paste-paste form was used for luting. The prepared teeth were cleaned with 35% phosphoric acid (Scotchbond Etchant; 3M ESPE) for 15 seconds and rinsed for 10 seconds. Excess water was removed using a mini-sponge (3M ESPE) to leave the prepared tooth moist. Two successive coats of dentin adhesive (3M Single bond adhesive; 3M ESPE) were applied and dried for 5 seconds. Each bonding surface was light polymerized for 10 seconds at 5-mm distance and an intensity of irradiation 130 mW/cm^2 (FutoLux 2; Carlo De Gorgi, Baranzate di Bollate, Italy). Equal amounts of Paste A and B of the RelyX ARC resin cement were extruded onto the mixing pad, mixed for 10 seconds, and applied to the intaglio surface of the crown.

In group FC, the resin-modified glass-ionomer cement GC Fuji CEM in 2-paste form was used for luting. Prepared teeth were treated using conditioner (GC Fuji CEM) for 20 seconds. Equal amounts of the 2 pastes were extruded onto the mixing pad and mixed in a thin layer using a plastic spatula for 10 seconds. For the ZP specimens, a fast-setting zinc phosphate cement (Harvard) was used for luting and served as the control. The recommended powder/liquid ratio (1 spoon/2-3 drops) was applied onto a paper mixing pad and mixed for 40 seconds using a metal spatula.

For all groups, the mix was applied to the intaglio surface of each crown. Each crown was seated on its respective prepared tooth with finger pressure. Excess cement was removed from the margins. The margins of specimens cemented with RelyX ARC resin cement were light polymerized for 40 seconds at 5-mm distance and an irradiation intensity of 130 mW/cm^2 (FutoLux 2; Carlo De Gorgi) to initiate polymerization of the resin cement. A 40-N static load was applied for 10 minutes with a loading apparatus. One hour after cementation, all specimens were stored in water bath at 37°C for 1 week before testing. To mimic the intraoral environment, half of the specimens in each subgroup (n=8) were fatigued in a computerized masticatory simulator (Willitec Kausimulator Version 3.1.3; Willitec,

Table II. Static fracture load (N) of all groups with and without cyclic loading

Groups	Without cyclic loading Mean (SD)	Median	Minimum/Maximum	With cyclic loading Mean (SD)	Median	Minimum/Maximum
NT	1140.1 (259.4)	1195.2	658.3/1439.6	1066.2 (307.1)	958.3	808/1075.3
MZ100 ZP	827.1 (86.3)	851.6	705.8/922.5	552.5 (123.6)	550.5	403.2/768.3
MZ100 FC	914.7 (131.7)	918.2	656.1/1062.3	706.2 (122.8)	684	530.1/901.6
MZ100 RX	955.9 (130.6)	970.4	697.8/1092.8	724.4 (117.8)	700.1	611.3/912.1
Vita ZP	772.3 (134.7)	764.3	588/984.3	571.5 (117.9)	564.5	400.2/827.1
Vita FC	923.6 (153.5)	979.8	665.9/1072.5	721.1 (141.5)	691.3	582.5/981.2
Vita RX	929.1 (148.5)	912.7	666.6/1106.6	752.7 (99.6)	777.1	602.3/900.5

NT, Natural teeth; *MZ100 ZP*, MZ100 zinc phosphate; *MZ100 FC*, MZ100 Fuji CEM; *MZ100 RX*, MZ 100 RelyX ARC; *Vita ZP*, Vita Mark II zinc phosphate; *Vita FC*, Vita Mark II Fuji CEM; *Vita RX*, Vita Mark II RelyX ARC.

Table III. Results of 3-way ANOVA

Source	*df*	Sum of squares	Mean square	F	P
Luting agent	2	474015.5	237007.7	14.2	<.001
Cyclic loading	1	1116575.4	1116575.4	70.5	<.001
Crown material	1	71.5	71.5	0.005	.947
Luting agent × Crown material	2	3634.6	1817.3	0.12	.892
Luting agent × Cyclic loading	2	5794.2	2897.1	0.183	.833
Crown material × Cyclic loading	1	12123.1	12123.1	0.76	.384
Error	86	1361009.2	15825.7		
Total	96				

Table IV. Results of *t* tests (*P* values) from multiple comparisons of luting agents, separated by cyclic loading

No cyclic loading	FC	RX	Cyclic loading	FC	RX
ZP	.012*	.003*	ZP	.002*	.001*
FC	–	.634	FC	–	.55

For group codes, see Table II; crown materials were pooled.
*Significant difference according to Bonferroni-Holm ($P<.05$).

Munich, Germany) under wet conditions for 600,000 masticatory cycles and 3500 thermal cycles (58°C/4°C) with a dwell time of 60 seconds. The loading cycle frequency was 1.2 Hz, with a kinetic energy of 2250×10^{-6} J, maximum load 49 N and minimum load 0 N, and lateral component 0.3 mm.[1,26] Steatite ceramic balls (4-mm diameter; Hoechst Ceram Tec, Wunsiedel, Germany) were used as antagonistic surfaces to simulate the opposite teeth. Specimens were mounted on stubs using autopolymerizing resin (Vitron M; 3M ESPE) and then fixed to the upper specimen holders in the masticatory simulator. The position of each test specimen was adjusted to ensure that the opposing ceramic ball contacted the triangular ridge of the palatal cusp of the crown. The other half (n=8) of each subgroup was fractured without cyclic loading fatigue.

For determination of the fracture load, a stainless steel bar with a 4-mm diameter ball end mounted in a screw-driven universal testing machine with a stepping motor (Z010; Zwick, Ulm, Germany) was used to apply compressive load along the long axis of restored and control teeth at a cross-head speed of 1 mm/min until fracture.[1,3] The compressive load (N) was centered on the central groove of each crown so that the load was applied to the triangular ridges of both facial and palatal cusps.[1,3] The compressive load required to cause fracture (N) was recorded for each specimen.

A 3-way analysis of variance (ANOVA) with post hoc multiple comparisons according to Bonferroni-Holm was used for statistical analysis. Crown materials in experimental groups were pooled for post hoc comparison with control groups. Allowing for different standard deviations, *t* tests for independent samples with unequal variances and Bonferroni-Holm correction were used. For all tests, the level of significance was set at α=.05. Statistical analysis was conducted using statistical software (SPSS, v. 10.0; SPSS Inc, Chicago, Ill).

RESULTS

The mean values, SDs, medians, and minimum and maximum fracture loads are listed in Table II for all groups. The ANOVA revealed a statistically significant influence of the luting agent and the cyclic loading ($P<.001$), whereas the crown material had no significant influence (Table III). No significant interactions between the parameters could be detected. Cyclic loading fatigue significantly decreased the mean fracture loads of the test groups independent of the crown material and the luting agents used for cementation.

However, independent of cyclic loading and crown material, adhesive luting agents FC and RX showed significantly higher fracture loads than conventional zinc phosphate cement (Table IV). Without cyclic loading, the differences of adhesively luted crowns (groups FC and RX) and natural teeth were not significant (FC,

Table V. Comparison of means of fracture loads of natural teeth for cyclic loading

	Cyclic loading	N	Mean	SD	P
Natural teeth	None	8	1140.1	259.4	
Natural teeth	Yes	8	1066.2	307.1	.611

P=.051) and (RX, *P*=.074), whereas conventionally cemented crowns exhibited significantly lower fracture loads (ZP, *P*=.007). However, after cyclic loading, all crown groups showed significantly lower fracture loads than natural teeth (RX, *P*=.019; FC, *P*=.014; and ZP, *P*=.002) stressed by cyclic loading. Also, cyclic loading did not decrease the fracture loads of unprepared natural teeth significantly (Table V).

DISCUSSION

The resulting failure loads (N) were ranked and compared to natural teeth loaded under identical conditions. Clinically, a similar loading occurs, and in a given situation, it will never be possible to calculate the specific loading surface when a restoration fails. However, the mean masticatory forces during mastication and swallowing in humans have been reported to be approximately 40 N,[3] whereas the mean maximum posterior masticatory forces vary from 200 to 540 N.[1,3] In this in vitro study, the mean fracture loads for composite resin and all-ceramic crowns cemented using adhesive resin cement or resin-modified glass-ionomer cement were higher than the mean maximum masticatory forces, even after cyclic loading. Therefore, it can be assumed that both crown systems, when luted using adhesive resin cement and resin-modified glass-ionomer cements, could withstand intraoral masticatory forces. This assumption is supported by the fact that without cyclic loading, there were no significant differences between the mean fracture loads of the unprepared natural teeth and those of Vita Mark II and MZ100 crowns in cement groups FC and RX. After cyclic loading, control groups showed significantly higher fracture loads than Vita Mark II and MZ100 crowns. However, the mean fracture loads of these crowns were still higher than the mean maximum masticatory forces reported in the literature.

In several studies,[1,3,9] natural teeth were used as a control group for comparing fracture loads of metal-free esthetic crowns. Other studies[17] used metal-ceramic crowns as a control. However, unprepared natural teeth always serve as a true control, because the restorative goal of fixed prosthodontics is not to improve nature, but to restore the function, esthetics, and properties of the teeth to their original physiological level. Therefore, comparing fracture loads of metal-free esthetic crowns to unprepared natural teeth may show best whether this goal was achieved or not. In this in vitro study, the inherently large variability in the fracture load of control teeth could be attributed to the fact that the natural teeth were collected from different dental clinics over a 6- to 10-month period and stored in thymol solution.

In this in vitro study, natural teeth were prepared according to clinically established preparation criteria[1,3] and also according to the manufacturer recommendations for the materials investigated. Various finish lines have been used for metal-free esthetic crown preparations, such as a 0.9-mm chamfer, 1.2-mm chamfer, 1.2-mm shoulder, and 1.5-mm shoulder.[1,3,16] However, a circumferential shoulder finish line of 1.5 mm was the finish line used for all-ceramic crown preparation in several studies.[1,3,17,18] Therefore, in this in vitro study, a circumferential shoulder finish line of 1.5 mm was used. As only a 6-degree axial taper was used and the finish line was above the CEJ, tooth reduction was not aggressive. However, in clinical situations with a finish line below the CEJ, the width of the shoulder must be reduced accordingly, as teeth are smaller in the cervical region. From this study, however, no conclusion can be reached regarding the influence of modifying factors such as a finish line below the CEJ and a more conservative preparation on the fracture load of the restorations.

The luting procedures also followed clinical protocols to ensure a close simulation of clinically relevant conditions.[1,3,7] Vita Mark II crowns were etched using HF acid before cementation with resin-modified glass-ionomer and zinc phosphate cements. Because resin-modified glass-ionomer cement contains HEMA, etching and silanization of all-ceramic crowns improves bonding of this cement to the crowns.[21] Etching alone is source of micromechanical retention that will improve bonding with zinc phosphate cement.[19] Another factor is that HF acid etching may weaken the crowns to some degree, so this factor should be included for all test groups.

Several studies have reported that the microstructure of the crown material, the bond strength to the crown and tooth interfaces, and the luting agents may influence the fracture load of the definitive restoration.[1,17,25] According to the manufacturer, Vita Mark II block is a conventional feldspathic ceramic with fine-grain particle size, whereas MZ100 block is a millable composite resin formed of 85% by weight ultrafine zirconium-silica ceramic particles that reinforce a highly cross-linked polymeric matrix. The polymeric matrix consists of bisphenol-A-diglycidylether dimethacrylate (BisGMA) and triethylene glycol dimethacrylate (TEGDMA). Different inherent mechanical properties of the 2 esthetic materials used for crown fabrication, such as stiffness and flexural strength, may also have influenced the fracture loads. The manufacturers report the modulus of elasticity to be approximately 63 GPa for Vita Mark II and 15 to 20 GPa for MZ100 blocks, whereas the flexural strength is purported to range from 120 to

140 MPa for Vita Mark II and from 150 to 160 MPa for MZ100 blocks.

Although, intuitively, all-ceramic crowns should have improved mechanical properties compared to composite resin crowns, no significant differences in the mean fracture loads of Vita Mark II and MZ100 crowns were recorded independent of the luting agents and the loading conditions. This finding may be due to the optimized industrial manufacturing conditions of both CAD/CAM crown materials, with minimum risk of voids and volume defects.[1,3] In addition, MZ100 composite resin crowns have improved elastic properties compared to Vita Mark II all-ceramic crowns.[6] Thus, during load application, the composite resin crowns may demonstrate higher resiliency with more absorption of load, and consequently, the fracture load is increased. These results are in agreement with the findings of other investigators.[5,7-9,17] McCormick et al[22] reported that the luting agent had no effect on the fracture load of all-ceramic crowns. However, Behr et al[23] found that the magnitude of load required to fracture all-ceramic or fiber-reinforced composite resin crowns could be increased when they were cemented using adhesive resin cement. Moreover, the clinical fracture rate of all-ceramic restorations also decreased when they were luted with adhesive resin-based luting agents rather than cemented using traditional zinc phosphate or conventional glass-ionomer cements.[24] Vita Mark II and MZ100 crowns cemented using zinc phosphate cement demonstrated significantly lower fracture loads than when luted using adhesive resin and resin-modified glass-ionomer cements before and after cyclic loading fatigue.

Zinc phosphate cement was used as the control because it has been the traditional luting agent used for cementation for over 150 years. In addition, clinical studies[24] and in vitro studies[18,26] used it for cementation of all-ceramic restorations to compare the influence of different luting agents on the fracture load and microleakage of all-ceramic crowns.[26] The relatively poor mechanical properties and the brittle nature of set zinc phosphate cement compared to adhesive resin and resin-modified glass ionomer cements[19] may have resulted in high stress concentration at the luting interface, with debonding and decreased fracture loads of the crowns. These results are in agreement with the finding of Mormann et al.[18] Also, after cyclic loading, fracture loads of MZ100 composite resin crowns cemented using an adhesive resin luting agent were significantly higher than when cemented using resin-modified glass-ionomer cement. This may be due to the use of adhesive resin cement incorporated with dentin bonding agent. This combination resulted in stronger bond strength to the composite crowns through chemical bonding.

Factors other than fracture load may affect the longevity of metal-free esthetic crowns, such as translucency, color stability, and wear. These factors should be considered when selecting all-ceramic or indirect composite resin for fabrication of metal-free restorations. Although indirectly fabricated composite resin crowns showed early good esthetic results and less wear of the opposing natural teeth,[6,12,13] both clinical studies[12,13] and an in vitro study[14] reported that disadvantages in using direct and indirect composite resin restorations, such as increasing wear, deterioration of surface finish, discoloration, color instability, and fractures, remained. However, all-ceramic crowns cause excessive wear of the opposing natural teeth, with the exception of hydrothermal low-fusing glass ceramic.[4] Both Vita Mark II and MZ100 are monochromatic blocks, which could be an esthetic limitation to achieving color match of the cervical, middle, and incisal or occlusal one third of the tooth. However, according to the manufacturer, Vita Mark II crowns can be stained and glazed after finishing and final occlusal adjustment. The MZ100 blocks can be finished and polished, but not extrinsically stained.

Fatigue is described as a phenomenon in which the characteristics of materials change over time under constant conditions.[1,25] All-ceramic and composite resin crowns are process-dependent materials with limited capacity to decrease the concentration of stresses at a crack tip by deformation. Cyclic loading, especially under wet conditions, results in the propagation of small cracks that may initiate from processing-related porosities within the crowns.[10,27] These cracks combine to form a growing fissure that weakens the crown.[15,25,27] Moreover, the fracture load of Vita Mark II and MZ100 crowns may also be decreased by static fatigue, a stress-dependent chemical reaction between water and surface flaws that causes the flaws to grow to a critical dimension, allowing spontaneous crack propagation.[1,27] The combined adverse effect of cyclic loading and a wet environment caused the crowns to fracture under reduced compressive load, as reported in other studies.[1,27] A limitation of this study was that the specimens were prepared according to standardized preparation criteria. However, different preparation criteria, such as position of the finish line and the amount of tooth reduction, may influence the fracture load of these 2 metal-free esthetic materials. Another limitation was that natural teeth were used as controls. However, the standard of care is still metal-ceramic crowns when a full coverage restoration is required, so the use of metal-ceramic crowns as controls would be of value.

CONCLUSIONS

Within the limitations of this in vitro study the following conclusions were drawn:

1. Cyclic loading fatigue significantly decreased the fracture loads of the composite resin and all-ceramic

CAD/CAM crowns luted using zinc phosphate cement (P=.002), resin-modified glass ionomer cement (P=.014), and adhesive resin cement (P=.019).

2. There was no significant difference in the mean fracture load of composite resin and all-ceramic CAD/CAM crowns independent from the loading conditions and luting agents.

3. Adhesive cementation increased fracture loads of composite resin and all-ceramic CAD/CAM crowns as compared to conventional cementation with zinc phosphate cement. This increase was significant before cyclic loading, for adhesive resin cement (P=.003) and resin-modified glass-ionomer cement (P=.012), and after cyclic loading, for adhesive resin cement (P=.001) and resin-modified glass ionomer cement (P=.002).

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