Novel-design ultra-thin CAD/CAM composite resin and ceramic occlusal veneers for the treatment of severe dental erosion

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Statement of problem. Ultra-thin bonded posterior occlusal veneers represent a conservative alternative to traditional inlays and complete coverage crowns for the treatment of severe erosive lesions. There is a lack of data regarding selection of the most appropriate material and its influence on fatigue resistance, which may affect restoration longevity.

Purpose. The purpose of this study was to assess the influence of CAD/CAM restorative material (ceramic vs. composite resin) on fatigue resistance of ultra-thin occlusal veneers.

Material and methods. A standardized nonretentive tooth preparation (simulating advanced occlusal erosion) was applied to 40 extracted molars including removal of occlusal enamel, and immediate dentin sealing (Optibond FL). All teeth were restored with a 0.6 mm-thick occlusal veneer (Cerec3 chairside CAD/CAM system). Reinforced ceramics (Empress CAD and e.max CAD) and composite resins (Paradigm MZ100 and XR (experimental blocks)) were used to mill the restorations (n=10). The intaglio surfaces were HF-etched and silanated (reinforced ceramics) or airborne-particle abraded and silanated (composite resins). Preparations were airborne-particle abraded and etched before restoration insertion. All restorations were adhesively luted with preheated Filtek Z100. Cyclic isometric loading was applied at 5 Hz, beginning with a load of 200N (x5,000), followed by stages of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each. The number of cycles at initial failure (first cracks) was recorded. Specimens were loaded until catastrophic failure (lost restoration fragment) or to a maximum of 185,000 cycles. Groups were compared using the life table survival analysis (α=.008, Bonferroni-method).

Results. Empress CAD and e.max CAD initially failed at an average load of 500N and 800N, respectively with no specimen withstanding all 185,000 load cycles (survival 0%); with MZ100 and XR the survival rate was 60% and 100%, respectively.

Conclusions. Both composite resins (MZ100 and XR) increased the fatigue resistance of ultra-thin occlusal veneers (P<.001) when compared to the ceramics evaluated (Empress CAD and e.max CAD). (J Prosthet Dent 2011;105:217-226)

Clinical Implications

CAD/CAM composite resins may provide better fracture resistance for nonretentive ultra-thin occlusal veneers in posterior teeth with high load requirements. If porcelain is required, e.max CAD may be indicated only for normal occlusal conditions.

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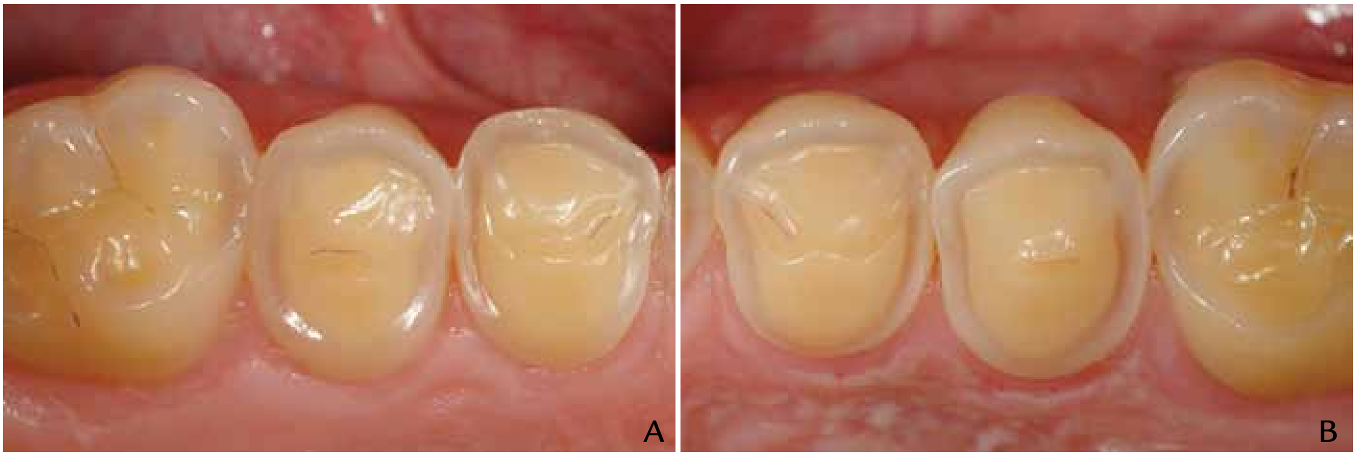


1 A-B, Severe erosion of 32-year-old patient caused by gastroesophageal reflux disease. Courtesy of Dr. Fransesca Vailati, University of Geneva, Switzerland.

The progressive reduction of enamel thickness is a biological condition resulting from the aging process.[1] However, the premature and accelerated loss of enamel by gastroesophageal reflux disease (GERD) or bulimia nervosa may occur in adolescence or childhood, with destructive consequences (Fig. 1).[2,3] As mineral loss is slow, gradual and often painless,[4] dental erosion is usually unnoticed by parents, patients and even dentists. It is habitually diagnosed at an advanced stage of the disorder, when a substantial loss of dental tissue has occurred[3,5-7] While the treatment for dental erosion should be initially focused on the etiology and prevention of further destruction,[3,8] the restorative phase requires a careful approach, depending on the degree of damage. Incipient lesions may only call for a clinical follow-up (for example, standardized photographs and accurate periodic impressions), noninvasive dentin sealing with a filled dentin bonding agent, or conservative direct composite resin restorations.[3]

However, treatment of patients with severe generalized erosion and wear is more complex. Clinicians may disagree about the best restorative strategy that also fulfills the complex occlusal requirements.[5-7] The major challenges are 1) wear may have been compensated by tooth eruption (maintaining occlusal vertical dimension), 2) restoring the shape and anatomy of the dentition often involves reducing sound dental tissues and 3) there is a wide range in the amount of reduction required by the different restorative approaches.[9] In addition, restorative procedures must also consider the patients' desires and awareness of esthetics and tissue conservation.[10] Treatment involving more tooth reduction, for patients where substantial amount of dental tissues have already been lost by erosion, may be considered inappropriate.

Restoring advanced erosive lesions solely by using additive adhesive techniques, allowing strategic minimal reduction of sound dental structure (non-retentive design or preferably "no preparation"), may be the best alternative.[11-14] It is not known, however, which restorative material is best. Only bonded ceramics and composite resins address the previously mentioned biomimetic principles of utmost tissue conservation and esthetics. The choice of ceramics as an enamel replacement is advocated[10,11,15] and relies primarily on the strength and thickness of the material,[15,16] as well as on effective bonding to the underlying dental substrate,[17,18] mimicking the function of the dentinoenamel junction.[1] The development of ceramics that are stronger (such as lithium disilicate glass ceramic)[19] but still etchable and machinable[20] has extended the indications for bonded ceramic restorations.

The performance of composite resins have also improved significantly during the last decade,[21-24] through a superior bond between the different phases (enabling appropriate stress transfer)[25,26] and various post-polymerization treatments.[23,27] Key properties of composite resin restorations include their low abrasiveness to antagonistic teeth (enamel preservation)[28] and low elastic modulus, allowing more absorption of functional stresses through deformation.[29] Fatigue resistance of thick CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) composite resin overlays have exceeded that of porcelain ones.[30,31] However, there is a lack of data for ultra-thin ceramic and composite resin overlays or occlusal veneers.

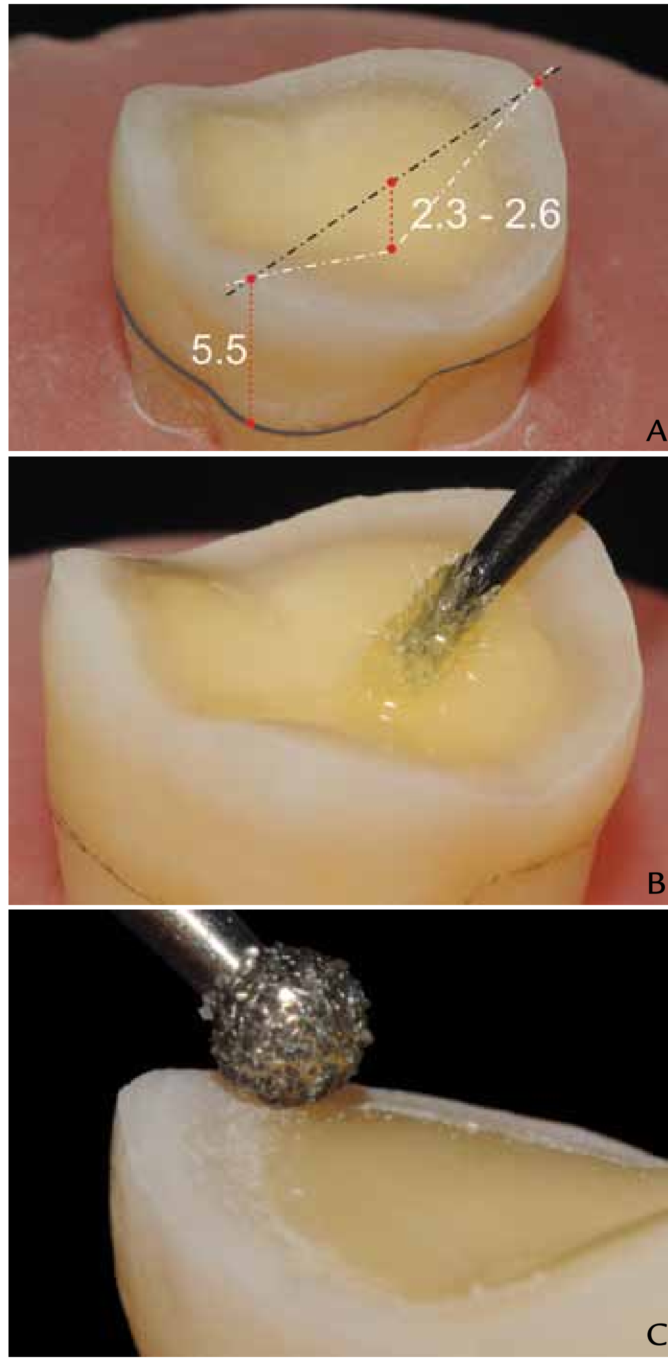
Therefore, the purpose of this in vitro study was to assess the influence of CAD/CAM restorative material (ceramic vs. composite resin) on the fatigue resistance of ultra-thin occlusal veneers. The null hypotheses were that (1) there would be no influence of material selection on the fatigue resistance of ultra-thin (0.6 mm thick) occlusal veneers, and (2) restoration thickness would have no influence of the fatigue resistance of occlusal veneers. This null hypothesis was tested by including previous data from the authors regarding 1.2 mm-thick occlusal veneers.

MATERIAL AND METHODS

Once approval was obtained from both the Ethical Committee of the Federal University of Santa Catarina and the University of Southern California Review Board, 40 freshly extracted sound human maxillary molars were stored in 0.1% thymol solution (Tymol Crystal; Merck KGaA, Darmstadt, Germany). Teeth were inserted in a special positioning device filled with acrylic resin (Palapress; Heraeus Kulzer GmbH, Hanau, Germany), embedding the root up to 3 mm below the cementoenamel junction (CEJ).

Tooth preparation

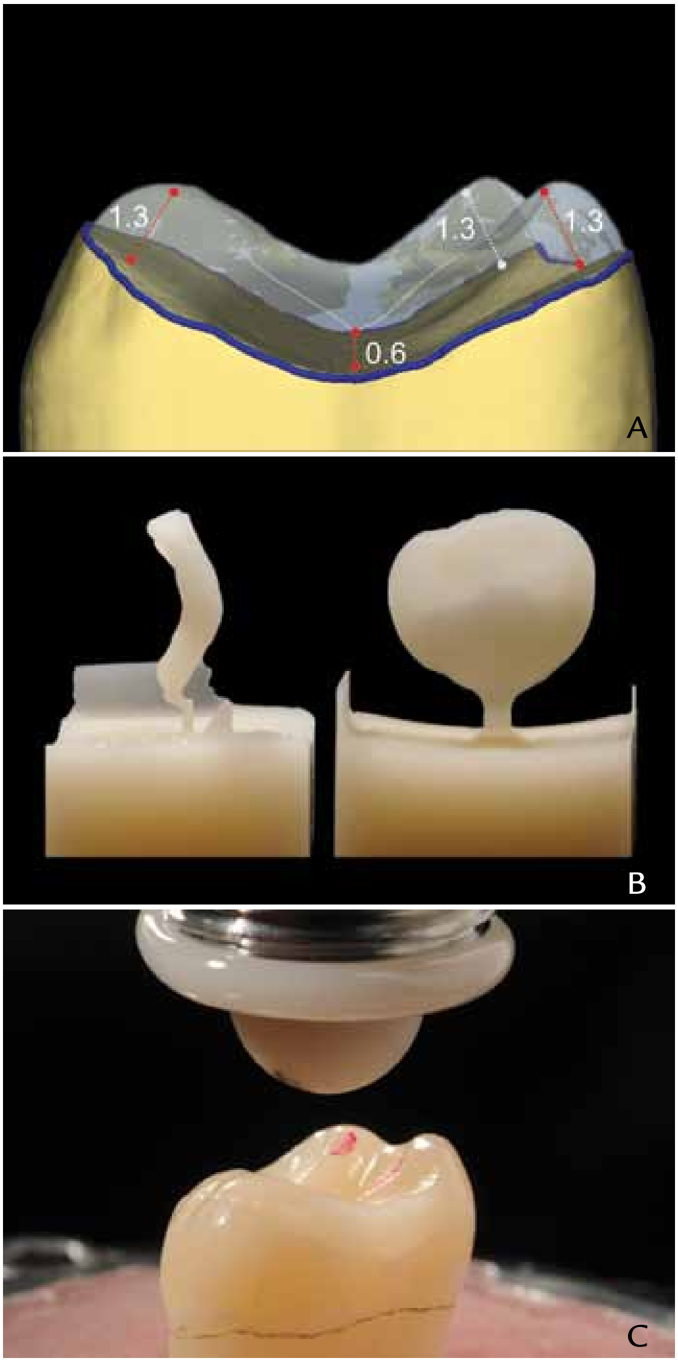
A standardized tooth preparation with the purpose of simulating advanced occlusal erosion was applied to all specimens. First, the occlusal enamel was selectively removed using a round-ended tapered diamond rotary cutting instrument (6850-023, Brasseler USA, Savannah, Ga). Cuspal inclination was kept as constant as possible by maintaining the buccal and palatal margins at approximately 5.5 mm from the CEJ and 2.3 to 2.6 mm above the central groove (Fig. 2A). Once the preparation was completed, immediate dentin sealing was accomplished using a 3-step etch-and-rinse dentin bonding agent (OptiBond FL; Kerr Corp, Orange, Calif) following the manufacturer's instructions: 15-second dentin etching with 37.5% phosphoric acid (Ultra-Etch; Ultradent, South Jordan, Utah), copious rinsing, careful air drying for 3-5 seconds with no desiccation, application of the primer with a light brushing motion for 15 seconds (Fig. 2B), air drying for 3-5 seconds, and application of adhesive resin only on dentin by gentle brushing for 20 seconds (no air thinning). The adhesive was then light-polymerized for 20 seconds at 1000mW/cm^2 (Allegro; Den-Mat, Santa Maria, Calif) with an additional 10 seconds under an air barrier (K-Y Jelly, Johnson & Johnson, New Brunswick, NJ) to reduce the oxygen-inhibition layer. Excess adhesive resin was then removed from the surrounding enamel with a round diamond rotary cutting instrument (801-023, Brasseler USA, Savannah, Ga) at 1,500 rpm (Fig. 2C). Each tooth was then stored in distilled water for 24 hours before the designing, machining and adhesive placement of the CAD/CAM restorations.



2 A, Tooth preparation with standard cuspal inclination (measurements and dimensions in mm). B, Immediate dentin sealing. C, Removal of excess adhesive resin from enamel.

Design and production of occlusal veneers.

The molars were restored using the Cerec 3 CAD/CAM system (Cerec software v3.03.; Sirona Dental Systems GmbH, Bensheim, Germany). All specimens were fitted with a standardized overlay from the Cerec database (third maxillary molar, Lee Culp Youth database). Using the Design Tools of the Cerec Software (version



3 A, Ultra-thin occlusal veneer with desired clearances (in mm). B, Inspection of 0.6 mm-thick ECAD restoration. C, Positioning specimen before testing (7 mm-diameter resin sphere) following adhesive placement and finishing.

3.03; Sirona Dental Systems) set in Master Mode, the occlusal surface was positioned to generate an average thickness of 0.6 mm at the central groove, maximum of 1.3 mm at the cusp tip and 1.0 mm at the internal cusp slope (Fig. 3A). With the purpose of standardization in form and anatomy, the design of the restoration was obtained by the sole use of the "position" tools (translation and rotation), without editing of the original shape produced by the software.

Twenty restorations were milled using reinforced glass ceramics, 10 from leucite ceramic blocks Empress CAD (Ivoclar Vivadent AG, Schaan, Liechtenstein) (group ECAD) and another group of 10 restorations from lithium disilicate blocks e.max CAD (Ivoclar Vivadent AG) (group EMAX). Twenty restorations were milled using composite resin blocks, 10 from Paradigm MZ100 blocks (3M ESPE, St Paul, Minn) (group MZ100) and another group of 10 restorations from XR experimental blocks (reinforced with short polyethylene fibers) (Kerr Corp) (group XR). A power analysis to determine adequate sample size was not performed.

All restorations were milled in Endo mode with the sprue located at the lingual surface (Fig. 3B) and inspected to detect eventual cracks generated by milling. For lithium disilicate blocks, restorations were crystallized in a ceramic furnace (Austromat D4; DEKEMA Dental-Keramiköfen GmbH, Freilassing, Germany) according to the manufacturer's recommendations (Ivoclar Vivadent AG). ECAD and EMAX restorations were polished using diamond ceramic polishers (Dialite; Brasseler USA), while MZ100 and XR were finished with brushes (Jiffy Composite Polishing Brushes; Ultradent).

Adhesive placement

Surface conditioning of ceramic restorations included 9% hydrofluoric acid etching (Porcelain Etch; Ultradent), 60 seconds for ECAD and 20 seconds for EMAX. Following thorough rinsing for 20 seconds, post-etching cleaning included brushing the restorations with phosphoric acid (Ultraetch) for one minute, followed by rinsing for 20 seconds and immersion in distilled water in an ultrasonic bath for 3 minutes. After air drying, the intaglio surfaces were silanated (Silane, Ultradent) and heat dried at 100°C for 5 minutes (DI500 oven; Coltène AG, Alstätten, Switzerland). The same protocol was used for restorations of groups MZ and XR except the hydrofluoric etching step, which was replaced by airborne-particle abrasion with 27-μm aluminum oxide at 30 psi (Rondoflex plus 360; KaVo Dental, Charlotte, NC).

Tooth preparations were all airborne-particle abraded (Rondoflex plus 360; KaVo Dental) and etched for 30 seconds with 37.5% phosphoric acid (Ultra-Etch; Ultradent), rinsed and dried. The adhesive resin (Optibond FL, bottle 2; Kerr Corp) was applied to both fitting surfaces of the restoration and the tooth and left unpolymerized. Following the application of the preheated luting material to the tooth (Filtek Z100; 3M ESPE), preheated at 68°C in Calset (AdDent, Danbury, Conn) the restoration was carefully seated and then subjected to a standardized load of 6N (by applying weights through a custom device) during excess luting material removal (CompoSculp DD1/DD2; Suter, Chico, Calif) and initial light-polymerization.[12,32] Each surface was exposed at 1000mW/cm2 (Allegro; Den-Mat) for 60 seconds (20 seconds per surface, repeated 3 times). The margins were then covered with an air barrier (K-Y Jelly; Johnson & Johnson) and light-polymerized for an additional 20 seconds. The margins were finished and polished with diamond ceramic polishers (W16DG, W16DM, W16D; CeramiPro Dialite; Brasseler USA) (all groups) and silicon carbide impregnated bristle brushes (Regular Jiffy Composite Polishing Brush; Ultradent) (MZ100, XR). Each specimen was then stored in distilled water at ambient temperature for 24 hours before testing.

Fatigue testing

Masticatory forces were applied using closed-loop servo-hydraulics (MiniBionix II MTS Systems, Eden Prairie, Minn) with a 7 mm-diameter composite resin sphere (Filtek Z100, 3M ESPE) post polymerized at 100°C for 5 minutes (Fig. 3C). Because of the standardized occlusal anatomy, each specimen was placed into the load chamber in the same and reproducible position with the load sphere contacting simultaneously and equally the mesiobucal, distobucal and lingual cusps (tripod contact). The load chamber was filled with distilled water until complete immersion of the specimen. Isometric mastication (under load control) was simulated at a frequency of 5 Hz, starting with a load of 200N for 5,000 cycles (preconditioning phase to guarantee predictable positioning of the sphere with the specimen)[33] followed by stages of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each. The number of cycles endured at initial failure (see below in crack detection and tracking) was recorded. Specimens were loaded until catastrophic failure (lost restoration fragments) or to a maximum of 185,000 cycles.

Crack detection and tracking

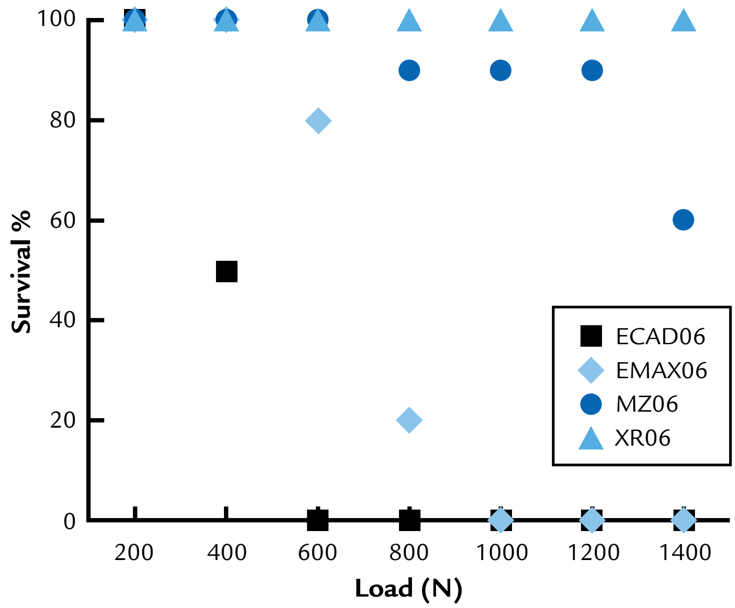
Initial failure was considered when a visible crack was detected and met 2 criteria: length greater than or equal to 2 mm, and involved the surface of the restoration. Such criteria were established because subsurface cracks or cracks smaller than 2 mm are particularly difficult to diagnose under normal clinical conditions. At the end of each load step, the specimens were evaluated in a 2-examiner agreement by transillumination (Microlux; AdDent, Inc), optical microscope at ×10 magnification (Leica MZ 125; Leica Microsystems GmbH; Wetzlar, Germany), and photographed under standardized conditions at ×1.5 magnification (Nikon D70 and Medical Nikkor 120mm lens and close up lens; Nikon, Tokyo, Japan). The crack tracking procedure was performed until catastrophic failure or until completion of the 185,000 cycles.

The 4 groups' endurance was compared using the life table survival analysis. At each time interval (defined by each load step), the difference between the specimens starting the interval intact and the specimens cracking or failing during that interval was counted, providing the survival probability (%) at each load step. The influence of the restorative material on the cracking propensity was observed comparing the survival curves using the log rank test at a significance level of .05. Differences were localized using pairwise post hoc comparisons with the same test at a significance level of .008 (Bonferroni correction for 6 comparisons). The statistical analysis was performed with MedCalc, v11.0.1. (Mariakerke, Belgium). Additional data from a previous study about 1.2 mm-thick occlusal veneers by the same operators and author in controlled identical conditions[12] were included. The life table survival analysis was used to compare the fatigue resistance of 0.6 mm vs. 1.2 mm ECAD and EMAX ceramic occlusal veneers. The influence of the thickness on the crack propensity was analyzed by using the log-rank test at a significance level of .05. Pairwise post hoc comparisons were used to locate the differences at an alpha value of 0.008 (Bonferroni correction for 6 comparisons).

RESULTS

In group ECAD, restorations failed (initial failure) at an average load of 500N (38,475 cycles), in group EMAX at an average load of 800N (87,089 cycles) and none of the specimens withstood all 185,000 load cycles (survival = 0% for both ECAD and EMAX). For groups MZ100 and XR the survival rate was 60% and 100%, respectively. Life table survival analysis (Fig. 4) revealed significant differences among groups ($P<.001$). Post hoc tests (Table I) showed higher fatigue resistance of MZ100 compared to ECAD and EMAX (P<.001 for both) and higher fatigue resistance of EMAX compared to ECAD (P<.001). XR was also significantly stronger than ECAD and EMAX ($P<.001$) but not different from MZ100 ($P=.03$). Among the 40 specimens, 3 teeth (all in group ECAD) demonstrated failure with loss of a restoration fragment (Fig. 5). However, none of the specimens experienced loss or significant damage of intact tooth structure.

Comparisons of 0.6 mm and 1.2 mm-thick ceramic occlusal veneers (Table II) showed higher fatigue resistance of EMAX (1.2 mm-thick) compared to ECAD (1.2mm-thick), EMAX and ECAD (P<.001 for all groups). ECAD (1.2mm-thick) was

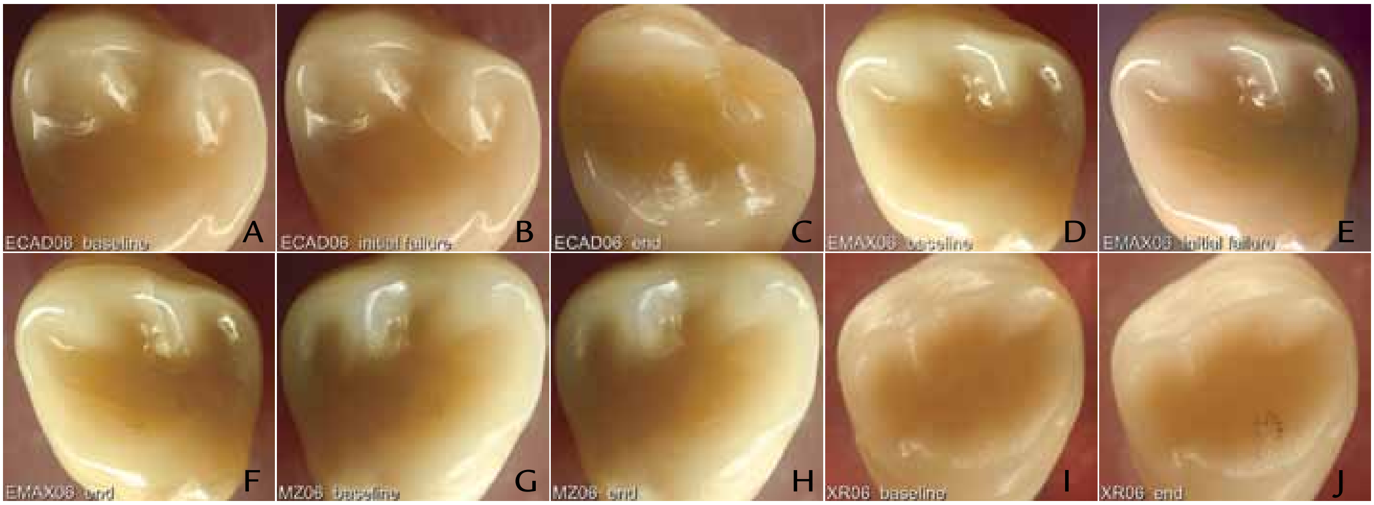


4 Life table survival distributions by materials at each load step (n=10).

TABLE I. Pairwise post hoc comparisons with the log-rank test (present study)

	ECAD	EMAX	MZ100	XR
ECAD		<.001	<.001	<.001
EMAX			<.001	<.001
MZ100				0.03
XR				

Significant differences between materials for *P* values <.008 (Bonferroni-corrected for 6 comparisons).



5 A-C, Specimen in group ECAD. A, Before testing. B, At initial failure (400N). C, Lost fragment at 1400N. D-F, Specimen in group EMAX. D, Before testing. E, At initial failure (800N). F, After 185.000 cycles. G,H, Survived specimen in group MZ100. G, Before testing. H, After testing. I, J, Survived specimen in group XR. I, before testing. J, After testing.

Table II. Pairwise post hoc comparisons with the log-rank test including previous data

	ECAD	EMAX	ECAD/1.2	EMAX/1.2
ECAD		<.001	<.001	<.001
EMAX			.103	<.001
ECAD/1.2				.001
EMAX/1.2				

Significant differences between porcelain tested (ECAD and EMAX: 0.6 mm-thick), including groups from previous study[12] (ECAD/1.2 and EMAX/1.2: 1.2 mm-thick) with *P* value of 0.008 (Bonferroni-corrected for 6 comparisons).

also significantly stronger than ECAD (*P*=.0001) but not different from EMAX (*P*=.1027).

DISCUSSION

The null hypotheses were rejected because, 1) composite resins MZ100 and XR had significantly increased fatigue resistance with ultra-thin posterior occlusal veneers when compared to the ceramics Empress CAD and e.max CAD, and 2) the restorative material thickness influenced the fatigue resistance. The study also demonstrated the feasibility of minimally invasive CAD/CAM ceramics and composite resins to treat severe erosion lesions in posterior teeth.

CAD/CAM technology was chosen due to its ability to control thickness and anatomy of restorations during the fabrication process. It also allowed the standardization of the internal fit of the restoration as well as the mechanical properties of the restorative materials.[20] Many potentially confounding operator variables were avoided such as dental laboratory technicians' skills and procedures involved in the fabrication process. This is especially important when using ultra-thin occlusal veneers. It can be questioned whether modern CAD/CAM technology would allow the machining of restorations less than 1 mm thick (Fig. 3B). Each restoration was carefully inspected after milling, before and after insertion. In view of the results of the present study, that thin occlusal veneers (0.6 mm at the central groove, maximum 1.3 mm at the cusp tip and 1.0 mm at the internal cusp slope) can be milled successfully with all the materials tested. Post-milling cracks were observed only in 2 instances and, there were no major marginal defects in any of the restorations. It is difficult to determine whether those cracks were already inside the blocks or were generated during the milling process. According to Tsitrou and van Noort,[9] who tried to fabricate thin crowns (0.6 mm occlusal reduction) using ceramic and composite resin blocks, only MZ100 could be milled ultra-thin without defects or cracks. The ability to mill thin restorations may therefore also be influenced by the type of preparation (crown versus non-retentive occlusal veneer).

The design used in this study (accelerated fatigue over the course of one day for each specimen), originally introduced by Fennis[33] and used in several studies by Magne and Knezevic,[30,31,34] constitutes a reasonable balance between the simple load-to-failure test and more sophisticated fatigue tests (minimum 1,000,000 cycles).[30,31] In the load-to-failure test, the specimen is forced to fail under displacement control of the load apparatus (similar to an automotive crash test). This provides useful data under extreme conditions but little significance regarding clinical endurance. However, the time-consuming aspect of true fatigues tests (low-load/high-cycle) is a significant limitation. Fatigue behavior of dental materials is characterized by a well-defined fatigue limit, above which the material fails quickly and below which there is long-term survival.

The present study design encompasses a wide range of clinically-relevant situations. The first half of the test lies inside the range of realistic occlusal forces in the posterior region, namely 8 to 880 N[35] that covers loads from mastication and swallowing until bruxism, respectively. The second half comprises the range of loads rarely reached in ordinary circumstances, yet it covers situations such as trauma (high extrinsic loads)[30,31] or intrinsic masticatory accidents (under mastication loads but delivered to a small area due to a hard foreign body such as a pit or seed).[36] The decision for using a composite resin sphere rather than stainless steel is also unique to this study but was previously suggested by Magne and Knezevic.[31] According to Kelly,[37] steel indenters tend to generate localized and intense point load, which are more likely to generate surface damage and powder-like debris by crushing (Hertzian cone-cracks). The lower stiffness and higher wear of the composite resin sphere allowed more realistic simulation of tooth contacts through wear facets distributing the load without reaching the compressive limit of the tissues or restorative materials.

At the beginning of the test (200 N load step), the intact ball generated contact pressure of approximately 200 MPa (3 contacts for approximately 1 mm^2), while at the end of the fatigue test (1400 N), the worn ball produced a contact pressures of only 350 MPa (approximately 4 mm^2). The intrinsic wear of the antagonistic load sphere allowed the contact pressure not to increase as fast as the increasing load. Kelly[37] mentioned this essential aspect of this test, and suggested using large radii spheres or indent the specimen to re-

6 Specimen after testing in group ECAD ("mosaic-like" cracks).

duce the increase in contact pressure. It was also important to ensure that the composite resin used for the fabrication of the load sphere was strong enough to undergo the entire fatigue test and maintain contact regardless of the load step. Therefore, the load cusps were carefully inspected at each load step and only one sphere had to be replaced due to delamination. A fully functional restored natural tooth could be simulated, which represents the uniqueness of this protocol. Simulation of the periodontal ligament was omitted, because elastomers or silicone films usually used for this purpose may have accelerated degradation; this would allow for excessive displacement of the tooth and could destabilize the servo-hydraulic control system.

Enamel and dentin are unique tissues with highly specialized function. When restoring a tooth one should consider not only the restorative materials that best emulates enamel and dentin, but also consider the simulation of the DEJ through the interfacial restoration-dentin bond,[30,31] which can be considered a true composite structure.[25] Using extremely thin "enamel-like" restorations, the bonding strategy becomes yet more important. Immediate dentin sealing (to seal freshly cut dentin surfaces with a dentin bonding agent immediately following tooth preparation, prior to making impressions), associated with a preheated light-polymerized composite resin restorative material, as a luting agent,[11,30,31,38] were used in this study. The advantages of this technique[39-41] were evident, since in the ceramic groups, only 3 restorations lost fragments (ECAD at > 1000N with minimal involvement of the dentin bond), while all of ECAD restorations displayed multiple "mosaic-like" cracks (Fig. 6). Among practical advantages of using a light-polymerizing restorative material to cement the occlusal veneer is the unlimited time to place the restoration (compensating the difficulty of positioning them, because of the lack of insertion path).

The results of the present study agree with the findings by Magne and Knezevic,[30] who demonstrated an increase in fatigue resistance of endodontically treated molars restored with MZ100 when compared to porcelain (MKII, VITABLOCS MARK II; Vident, Brea, Calif). Nevertheless, in the present study, no specimen underwent catastrophic failures in the remaining tooth structure. Cracks were restricted to the restorations and remaining enamel. This fact highlights the advantage of minimally invasive strategies,[13,14,42] preserving the structural integrity of the teeth. The first cracks (initial failure), observed in both ECAD and EMAX groups could be explained by a previous numeric simulation.[43] The high tensile stresses in the central groove could not be withstood by the brittle ceramics.[43] Therefore, the energy was released by means of new surfaces, namely cracks[37] (Figs. 5 and 6). From the present data it appears that the higher uniaxial flexural strength of ceramic blocks (256 and 127 MPa for EMAX and ECAD, respectively), compared to that of composite resin blocks (150 and 170 MPa for MZ100 and XR respectively), does not correlate with the survival rate (Fig. 3). In fact, strength data alone is unable to predict accurately the structural failure in complex structures made from multilayered materials.[44] The failure triggered by the development of tensile stresses is much more sensitive to the ratios of elastic moduli between the restorative material and the luting material and dentin, and much less to the intrinsic strength as well as the thickness of the material.[37] The relatively similar elastic modulus of the composite resin (approximately16-20MPa) and dentin (approximately18.5GPa)[45] may have a key role in the tooth-restoration performance of the composite resin groups. In addition, the findings seem to correlate with the work of fracture of the various materials ($K1c^2$/Emod): XR (571 J/m2) > Paradigm MZ100 (141 J/m2) > e.max CAD (83 J/m2) > Empress CAD (21 J/m2) (obtained from additional testing). The work of fracture represents the energy used within the fracture process where a new surface is generated and considers the elastic modulus of the material. Because of their higher strength, EMAX restorations started cracking at a step above that of ECAD restorations. This difference disappeared when the thickness of ECAD restorations was increased, as demonstrated when comparing 0.6 mm and 1.2 mm-thick ceramic occlusal restorations (Table II).

Assuming that the first cracks appeared at relatively high loads (end of the first half of the test) and that none of the ultra-thin restorations lost fragments, the lithium disilicate blocks can be recommended in patients with standard load requirements. However, the horizontal component from the axial loading was not able to threaten the composite resin restorations in both MZ100 and XR groups, confirming the possibility of using these materials for restoring posterior teeth with thin or ultra-thin occlusal veneers even under high load requirements. Although there were no statistical differences between the composite resins tested, the absolute survival of all restorations in group XR can be explained by the improvement of mechanical properties through inclusion of fibers.[46] While composite resin restorations are expected to wear more than ceramic, they also tend to preserve more of the antagonistic enamel.[28] This differential wear of CAD/CAM composite resin and ceramic occlusal veneers requires additional investigations, which is currently under way.

One should consider the discrepancy between the clinical definition of mechanical "survival" or "failure," usually based on the detection of cracks and fractures, and the "tooth-like" biomimetic approach to restorative dentistry.[1] According to the latter, enamel that is shown to be weaker and more brittle than the weakest and most brittle ceramic (for example, ECAD in the present study), is also acknowledged to provide optimal function throughout a lifetime, even when cracked. Cracking is an accepted physiological aging process in enamel. Should cracking be considered acceptable for dental materials too? The answer to this question is paramount to the interpretation of the present results and might generate a significant paradigm shift.[47]

CONCLUSIONS

Within the limitations of this in vitro accelerated fatigue study, it was concluded that:

1. CAD/CAM composite resin ultra-thin occlusal veneers significantly increased the fatigue resistance when compared to the ceramic ones.

2. None of ECAD and EMAX ultra-thin occlusal veneers withstood all 185,000 load cycles (survival = 0%); with MZ 100 and XR the survival rate was 60% and 100%, respectively.

3. There were no catastrophic failures but only cracks limited to the restorative material.

4. The CAD/CAM composite resins can be recommended for fabricating ultra-thin occlusal veneers in posterior teeth even in patients with high load requirements.

5. Among ceramic groups, only EMAX successfully underwent the first part of the fatigue test and can be deemed indicated for ultra-thin occlusal veneers under normal occlusal conditions.

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