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# Effect of Different Computer-aided Design/Computer-aided Manufacturing (CAD/CAM) Materials and Thicknesses on the Fracture Resistance of Occlusal Veneers

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### Clinical Relevance

Occlusal veneers composed of IPS e.max CAD, Vita Enamic, or Lava Ultimate with an 0.6-mm thickness are promising materials for the restoration of eroded posterior teeth.

## SUMMARY

**The aim was to evaluate, *in vitro*, the influence of different computer-aided design/computer-aided manufacturing (CAD/CAM) materials (IPS e.max CAD, Vita Enamic, and Lava Ultimate) and thicknesses (0.6 mm and 1.5 mm) on the fracture resistance of occlusal veneers. Sixty human third molars were prepared to simulate advanced erosion of the occlusal surface, and the teeth were randomly divided into six experimental groups (n=10) according to the material and thickness used to build the veneers. Ten sound teeth formed the control group. The veneers were adhesively luted and submitted to mechanical cyclic loading (1 million cycles at 200-N load). The fracture resistance test was performed in a universal testing machine. The failures were classified as "reparable" and "irreparable." According to two-way analysis of variance and the Tukey test, the interaction (material × thickness) was significant (*p*=0.013). The highest fracture resistance was obtained for IPS e.max CAD at a 1.5-mm thickness (4995 N) and was significantly higher compared to the other experimental groups (*p*<0.05). The lowest fracture resistance was obtained for Vita Enamic at 0.6 mm (2973 N), although this resistance**

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**was not significantly different from those for IPS e.max CAD at 0.6 mm (3067 N), Lava Ultimate at 0.6 mm (3384 N), Vita Enamic at 1.5 mm (3540 N), and Lava Ultimate at 1.5 mm (3584 N) (*p*>0.05). The experimental groups did not differ significantly from the sound teeth (3991 N) (*p*>0.05). The failures were predominantly repairable. The occlusal veneers of IPS e.max CAD, Vita Enamic, and Lava Ultimate, with thicknesses of 0.6 mm and 1.5 mm, obtained fracture resistances similar to those associated with sound teeth.**

## INTRODUCTION

The progressive reduction of dental enamel is a biological consequence of advancing age. However, the premature loss of this tissue may be due to the action of acidic foods and beverages, gastroesophageal reflux disease, bulimia nervosa, medications, and the reduction of salivary flow itself. These lesions are called dental erosion and have noncarious characteristics.[1,2]

The treatment of dental erosion should be approached by addressing the etiological factor of the disease, avoiding the progression of mineral loss. This mineral loss is slow, gradual, and often painless.[3] Dental erosion is usually not observed by patients and parents, and it is many times only diagnosed at an advanced stage when a substantial loss of dental tissue has occurred.[4] The recommended treatments to restore molars and premolars with severe erosion are indirect composite resin or ceramic restorations, such as inlays, onlays, or full crowns. However, some of these approaches can be very invasive.[5] Therefore, less invasive procedures should be the first treatment choice because of the advantages they offer, such as dental tissue preservation, maintenance of pulp vitality, and low rates of sensitivity.[6,7]

Computer-aided design/computer-aided manufacturing (CAD/CAM) technology became popular during the last decade for the preparation of restorations. This technology allows professionals to easily and quickly make restorations in a single session. Different materials are supplied in the form of blocks that are milled to obtain the restorations.[8]

Among CAD/CAM materials, reinforced ceramics, such as lithium disilicate (IPS e.max CAD), have recently expanded their indications to include thinner restorations. Ultrathin lithium disilicate occlusal veneers on posterior teeth have been shown[9] to be a conservative alternative to traditional inlays, onlays, and full crowns, with promising results.

Recently, a new material called a hybrid ceramic was launched on the market (Vita Enamic). This material consists of a hybrid structure of two interpenetrating networks of ceramic and polymer. Vita Enamic has been developed to allow faster milling of the ceramic block as well as ultrathin restorations (0.2-0.5 mm) with good mechanical behavior after luting.[10]

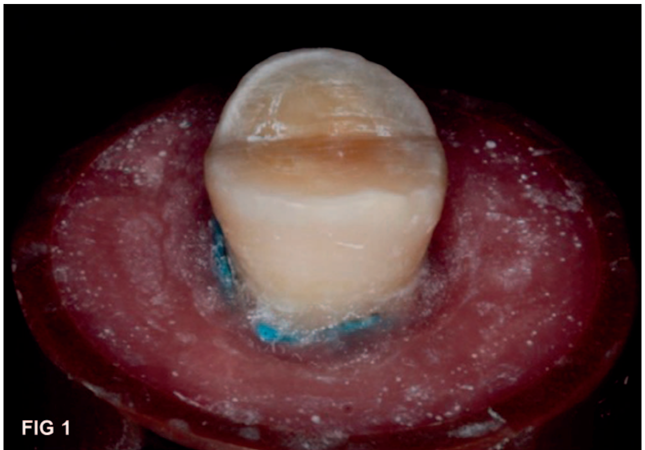
Composite resins represent another alternative for obtaining thin restorations in the occlusal region (Lava Ultimate), with superior fatigue resistance in comparison with the lithium disilicate–reinforced ceramic.[9] Lava Ultimate is a nano-filled resin composite, and this material has higher flexural strength and fracture toughness than do resin composites polymerized by a dental curing light.[11]

There is little information about the fracture resistance of Vita Enamic occlusal veneers compared with other restorative materials.[12] In view of the importance of dental tissue preservation, it is relevant to evaluate the fracture resistance of ultrathin occlusal veneers made with different restorative materials. Therefore, the aim of this study was to evaluate, *in vitro*, the influence of CAD/CAM restorative materials (IPS e.max CAD, Vita Enamic, and Lava Ultimate) and their thickness (0.6 mm and 1.5 mm) on the fracture resistance of teeth restored with occlusal veneers. The study was carried out under the following hypotheses: 1) the different thicknesses of the occlusal veneers do not influence the fracture resistance of the restored teeth; and 2) the different restorative materials do not influence the fracture resistance of the restored teeth.

## METHODS AND MATERIALS

### Tooth Selection

Human third molars, extracted for therapeutic reasons, were obtained after approval from the ethics committee (55675416.7.0000.5336). The teeth were examined under 10× magnification to verify the absence of cracks, caries, restorations, or fractures. The teeth were cleaned of gross debris, disinfected in 0.5% chloramine T for 24 hours, and then stored in distilled water at 4°C. The water was changed every week, and the teeth were used within six months. The buccal-palatal and mesiodistal dimensions of each tooth were measured with a digital caliper rule (500-197-20 Mitutoyo, Kawasaki, Japan). A variation of 0.5 mm was allowed for each measurement to standardize the dimensions of the teeth. In total, 70 teeth were selected, which were randomly distributed among seven different groups (n=10), as follows:



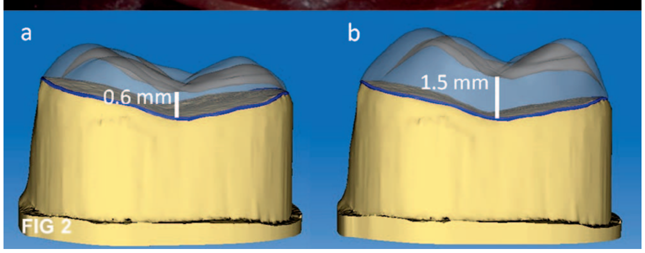




Figure 1. *Tooth preparation.*

Figure 2. *(a) Model of occlusal veneers with a thickness of 0.6 mm at the central groove and (b) model of occlusal veneers with a thickness of 1.5 mm at the central groove.*

1) sound teeth (control); 2) IPS e.max CAD 0.6 mm; 3) IPS e.max CAD 1.5 mm; 4) Vita Enamic 0.6 mm; 5) Vita Enamic 1.5 mm; 6) Lava Ultimate 0.6 mm; and 7) Lava Ultimate 1.5 mm.

### Periodontal Ligament Simulation

A layer of adhesive (Universal Tray Adhesive, Zhermack, Rovigo, Italy) was applied with a brush on the root portion of each tooth. After the adhesive was dried, a layer of regular-viscosity vinyl polysiloxane was applied (Express Standard, 3M ESPE, St Paul, MN, USA) to artificially represent the periodontal ligament.

### Tooth Preparation

Each tooth was mounted in a plastic cylinder filled with self-cured acrylic resin up to 2 mm below the cemento-enamel junction (CEJ) and then stored in distilled water at 4°C. The tooth preparation was performed according to the methods in the study by Magne and others.[13] A standardized preparation was performed on all teeth to simulate advanced erosion of the occlusal surface. First, the occlusal dentin was exposed by the selective removal of the occlusal enamel by applying a 4138 diamond bur (KG Sorensen, Cotia, SP, Brazil) at high speed with a water coolant. The buccal and lingual margins were maintained at approximately 5 mm from the CEJ and 2.3 to 2.6 mm above the central groove, maintaining the inclination of the cusps. The finished dental preparation was obtained with a 4138F diamond bur (KG Sorensen) (Figure 1). The diamond bur was replaced every five preparations.

### Manufacturing the Occlusal Veneers

The occlusal veneers were made by CAD/CAM using Cerec software (version 4.0.2, Sirona Dental Systems GmbH, Bensheim, Germany). The tooth preparation was sprayed with reflective titanium (VITA Zahnfabrik, Bad Säckingen, Germany) to create the opaque surface needed for scanning with an optical three-dimensional intraoral camera, creating a three-dimensional virtual impression. The shape of the occlusal veneers was designed with an individual biogeneric copy from a right second lower molar. The thickness of the occlusal veneers was defined in the software according to each experimental group (Figure 2). The virtual die spacer used was 50 μm without removal of retention.

Sixty occlusal veneers were fabricated in the milling unit: 20 in lithium disilicate glass-ceramic (IPS e.max CAD), 20 in hybrid ceramic (Vita Enamic) and 20 in nanoceramic resin (Lava Ultimate) (Table 1). Ten teeth remained sound (control). Of the 20 occlusal veneers with each material, 10 had a thickness of 0.6 mm and 10 had a thickness of 1.5 mm, the latter being the usual thickness recommended by the manufacturers of these different trademark products.

The occlusal veneers milled in IPS e.max CAD were crystallized in a ceramic furnace (Programat P300, Ivoclar Vivadent, Schaan, Liechtenstein) for 30 minutes at a final temperature of 850°C under vacuum. After removal of the sprue and polishing with rubber tips (Diagloss, Edenta, Au, Switzerland), the veneers were glazed at 770°C. Vita Enamic veneers were mechanically polished with the Vita Enamic polishing set (VITA). Lava Ultimate veneers were mechanically polished with silicone tip Optimize (TDV, Pomerode, SC, Brazil) and diamond paste Enamelize (Cosmedent, Chicago, IL, USA) with a felt disk.

### Luting Procedure

The luting procedures are described in Table 2. The resin cement was applied to the inner surface of the occlusal veneer. Immediately, the veneer was placed on the preparation and a load of 1 kg was applied by means of a metallic tool. The excess resin cement

Table 1: *Materials for Computer-aided Design/Computer-aided Manufacturing (CAD/CAM), Composition, and Manufacturers[a]*

| Material | Composition | Manufacturer |
|---|---|---|
| IPS e.max CAD Lithium disilicate ceramic | $SiO_2$, $Li_2O$, $K_2O$, MgO, $Al_2O_3$, $P_2O_5$, and other oxides | Ivoclar Vivadent, Schaan, Liechtenstein |
| Vita Enamic Hybrid ceramic | Ceramic: silicon dioxide 58%-63%, aluminum oxide 20%-23%, sodium oxide 9%-11%, potassium oxide 4%-6%, boron trioxide 0.5%-2%, zirconia and calcium oxide; Polymer part (25%): UDMA and TEGDMA | VITA Zahnfabrik, Bad Säckingen, Germany |
| Lava Ultimate nanoceramic resin | Silica nanomers (20 nm), zirconia nanomers (4-11 nm), nanocluster particles derived from the nanomers (0.6-10 nm), silane coupling agent, resin matrix (Bis-GMA, Bis-EMA, UDMA, and TEGDMA) | 3M ESPE, St Paul, MN, USA |

*Abbreviations: Bis-EMA, ethoxylated bisphenol A dimethacrylate; Bis-GMA, bisphenol A diglycidyl dimethacrylate; HEMA, hydroxyethyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate*
*[a] The chemical composition information was obtained from the manufacturer's material safety data sheets.*

was removed, followed by light-curing with an LED curing unit (Bluephase N, Ivoclar Vivadent) for 20 seconds in each face with a light intensity of 1000 $mW/cm^2$. The light intensity of the curing unit was monitored every five specimens with the aid of an LED radiometer (SDI, Bayswater, Victoria, Australia). The specimens were stored in distilled water at 37°C for 24 hours. After this period, the restorations received cyclic mechanical loading.

## Cyclic Mechanical Loading

The specimens were submitted to cyclic loading using the ER-11000 (Erios, São Paulo, SP, Brazil) cycling machine. The load profile was shaped as a sine wave and was always in contact with the occlusal surface of the veneers at 200 N using 1,000,000 cycles at 1 Hz in distilled water at 37°C. At the end of the cyclic loading, the presence or absence of luting failures, fractures, chips, or cracks on the veneers was observed with the aid of a 10× loupe (Olympus, Tokyo, Japan). The following classifications were used: a) success (unchanged); b) failure (fractures, chips, or cracks); or c) survival (a failure that did not interfere with the esthetics or use of the restoration).[14]

## Fracture Resistance Testing

The fracture resistance testing was performed in a universal testing machine DL-2000 (EMIC, São José

Table 2: *Application Steps of the Luting Procedures*

| Treatment/Material | IPS e.max CAD<br>Vita Enamic | Lava Ultimate |
|---|---|---|
| Tooth surface treatment | • Apply the 37% phosphoric acid (N Etch; Ivoclar Vivadent, Schaan, Liechtenstein) on enamel for 30 s and on dentin for 15 s<br>• Rinse the surface for 30 s and dry the surface with cotton buds<br>• Apply the ExciTE F DSC adhesive system (Ivoclar Vivadent, Schaan, Liechtenstein) with a microbrush and dry gently for 5 s | • Apply the 35% phosphoric acid (3M, St Paul, MN, USA) only on enamel for 30 s<br>• Rinse the surface for 30 s and dry the surface with cotton buds<br>• Apply the Single Bond Universal adhesive system (3M, St Paul, MN, USA) with a microbrush for 20 s and dry gently for 5 s. |
| Treatment of the inner surface of the veneers | • Apply the 5% hydrofluoric acid (Condac Porcelana, FGM, Joinville, SC, Brazil) for 20 s on IPS e.max CAD and for 60 s on Vita Enamic<br>• Rinse the surface for 30 s and air-dry<br>• Apply a layer of universal primer (Monobond-N, Ivoclar Vivadent, Schaan, Liechtenstein) and dry gently for 5 s | • Sandblasting with 50 μm aluminum oxide for 5 s.<br>• Rinse the surface for 30 s and air-dry<br>• Apply a layer of the Single Bond Universal adhesive system and dry gently for 5 s |
| Resin cement | • Mix equal lengths of the base and catalyst pastes of Variolink N (Ivoclar Vivadent, Schaan, Liechtenstein) for 15 s and put on the inner surface of the occlusal veneer | • Mix equal lengths of the base and catalyst pastes of RelyX Ultimate resin cement (3M, St Paul, MN, USA) for 15 s and put on the inner surface of the occlusal veneer |

Table 3: *Fracture Resistance Means (N) of the Experimental Groups*[a]

| Groups | n | Fracture Resistance Means, N | Standard Deviations |
|---|---|---|---|
| Vita Enamic 0.6 mm | 10 | 2973 A | 635 |
| IPS e.max CAD 0.6 mm | 10 | 3067 A | 933 |
| Lava Ultimate 0.6 mm | 9 | 3384 A | 922 |
| Vita Enamic 1.5 mm | 10 | 3540 A | 986 |
| Lava Ultimate 1.5 mm | 10 | 3584 A | 954 |
| IPS e.max CAD 1.5 mm | 8 | 4995 B | 855 |

[a] *Means followed by different letters represent significant differences according to Tukey test ($\alpha$=0.05).*

dos Pinhais, PR, Brazil) using a cell load of 10 kN and a crosshead speed of 1 mm/min. A metal sphere with a diameter of 6 mm was attached to the load cell, which was connected to the mobile arm of the testing machine. The metal sphere was positioned to achieve tripodization of contacts along the cuspal inclines over the central fossa. The compression load was applied parallel to the long axis of the restored tooth until it fractured. The maximum force was recorded in Newtons (N).

### Failures Analysis

After the fracture resistance testing, the specimens were visually assessed to determine the type of failure. The classification followed the criteria described by Beltrão and others,[15] as follows: 1) repairable and 2) irreparable. A fracture was considered irreparable when the fracture line divided the tooth into two parts at the floor level of the pulp chamber. The fractures were considered repairable when the fracture line involved only the restoration or all or part of the cusps.

### Statistical Analysis

The fracture resistance values were submitted to the Kolmogorov-Smirnov normality test. As there was normality, the results were analyzed by two-way analysis of variance (ANOVA) (veneer thickness × material), followed by Tukey test. One-way ANOVA followed by Tukey test was applied to compare the fracture resistance of the sound teeth (control) with that of the experimental groups. The significance level was 5%. The software used was SPSS 10.0 (SPSS Inc, Chicago, IL, USA).

## RESULTS

After cyclic loading, no cracks, chips, or fractures were observed in any sample.

According to two-way ANOVA, the material factor ($p$=0.031), the thickness factor ($p$=0.0004), and the interaction between the material and thickness ($p$=0.013) were significant.

A significantly higher fracture resistance was obtained for IPS e.max CAD 1.5 mm (4995 N) than for the other experimental groups ($p<0.027$). Lower fracture resistances, not significantly different from each other, were obtained for Vita Enamic 0.6 mm (2973 N), IPS e.max CAD 0.6 mm (3067 N), Lava Ultimate 0.6 mm (3384 N), Vita Enamic 1.5 mm (3540 N), and Lava Ultimate 1.5 mm (3584 N) ($p>0.550$) (Table 3).

There was a fracture of the acrylic resin base of three specimens, and the fracture resistance could not be obtained from these samples. These fractures occurred in one Lava Ultimate 0.6-mm specimen, two IPS e.max CAD 1.5-mm specimens, and one sound tooth.

According to one-way ANOVA, the fracture resistance of the sound teeth (3991 N) did not differ significantly from that of the experimental groups ($p>0.199$). Figure 3 compiles the fracture resistance means of the sound teeth (control) and experimental groups.

The failures were predominantly repairable for Lava Ultimate 0.6 mm, IPS e.max CAD 0.6 mm, IPS e.max CAD 1.5 mm, Vita Enamic 0.6 mm, and Vita Enamic 1.5 mm. The fractures were predominantly irreparable in sound teeth and Lava Ultimate 1.5 mm (Table 4).

Figure 4 shows examples of a reparable fracture (a) and an irreparable fracture (b).

## DISCUSSION

There was no significant difference in the fracture resistances of 0.6-mm and 1.5-mm-thick veneers made of Lava Ultimate and Vita Enamic. For IPS e.max CAD, the fracture resistance was significantly higher at a thickness of 1.5 mm compared to a thickness of 0.6 mm. Therefore, the first hypothesis was rejected.

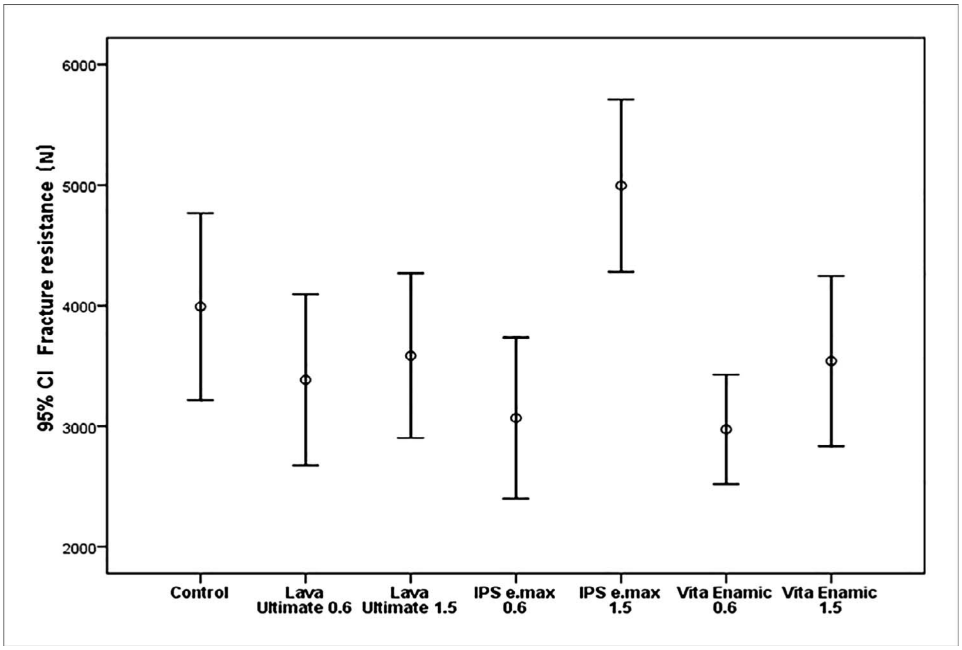



Figure 3. *Mean fracture resistances (N) of the sound teeth and experimental groups.*

Manufacturers of Lava Ultimate, IPS e.max CAD, and Vita Enamic indicate that restorations with a minimum thickness of 1.5 mm on the occlusal surface of posterior teeth will support masticatory loads. However, the results of the present study corroborate other *in vitro* studies[9,12,13,16,17] showing that it is possible to treat severe erosive lesions on posterior teeth with minimal wear using CAD/CAM ceramic and composite resin materials.

All of the restored teeth, regardless of the thickness of the occlusal veneers, obtained values above the maximum masticatory forces in humans. The maximum posterior masticatory force in an individual with no history of parafunction is approximately 424 N for women and 630 N for men.[18] In individuals with parafunction, the masticatory force in molars can vary from 780 N to 1120 N.[19] Additionally, there was no significant difference between the fracture resistance obtained for any of the experimental groups and the sound teeth (control). This finding is important because it shows that even when using ultrathin (0.6-mm) occlusal veneer restorations, the restored teeth showed similar fracture resistance to sound teeth. The possibility of making ultrathin occlusal veneers allows for a more conservative preparation with minimal wear to the tooth structure. It is believed that these positive results are due in part to the adhesive luting technique that allows intimate contact between the dental substrate, luting agent, and restorative material, so that the occlusal forces are applied and dissipated through the tooth, periodontal ligament, and alveolar bone.[20,21] Additionally, indirect restorations luted by the adhesive luting technique provided greater fracture resistance than do conventional luting techniques, such as zinc phosphate cement.[22] Therefore, the use of adhesive restorations has been recommended for reinforcing the remaining dental structure,[23,24] even if this recovery of resistance is only partial.[25,26]

In the present study, the luting protocol was not standardized for all groups, because the manufacturers of Lava Ultimate and IPS e.max CAD recommend the use of their own resin cement—RelyX Ultimate and Variolink N, respectively. The manufacturer of Vita Enamic recommends the use of VITA ADIVA full-adhesive (VITA Zahnfabrik), which is not sold in Brazil. The Brazilian representative of VITA, the Wilcos Company (Petrópolis, Rio de Janeiro, Brazil), recommends the use of resin cement in combination with an adhesive. For

Table 4: *Fracture Analyses of the Different Groups*

| Group/Fracture Analysis | Repairable Fracture | Irreparable Fracture | Total |
|---|---|---|---|
| Sound teeth | 3 | 6 | 9 |
| IPS e.max CAD 0.6 mm | 8 | 2 | 10 |
| IPS e.max CAD 1.5 mm | 6 | 2 | 8 |
| Vita Enamic 0.6 mm | 9 | 1 | 10 |
| Vita Enamic 1.5 mm | 6 | 4 | 10 |
| Lava Ultimate 0.6 mm | 6 | 3 | 9 |
| Lava Ultimate 1.5 mm | 4 | 6 | 10 |

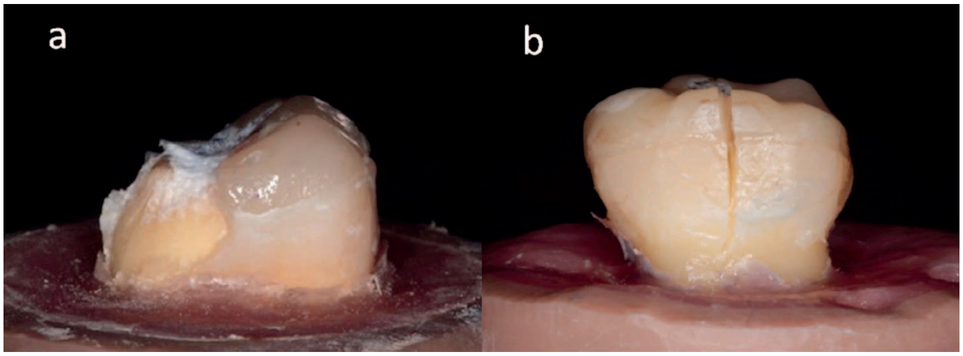



Figure 4. *(a) Reparable fracture—the fracture line involved the restoration and the cusp, and (b) irreparable fracture—the fracture line divided the tooth into two parts at the floor level of the pulp chamber.*

convenience, Variolink N was used for the luting of the occlusal veneers made with Vita Enamic.

For the adhesive luting of Lava Ultimate, the Single Bond Universal adhesive system was applied using the selective enamel etching technique. In this way, the self-etching mode on dentin was selected because better results are obtained from this mode than from the etch-and-rinse mode.[27] The ExciTE F DSC adhesive system was used for luting IPS e.max CAD and Vita Enamic, and the total-etch technique was applied because the manufacturer of this adhesive recommends this technique. To treat the inner surface of the restorations, the Lava Ultimate veneers were sandblasted with aluminum oxide particles, creating superficial irregularities that allow micromechanical retention with the applied adhesive.[28] The IPS e.max CAD and Vita Enamic veneers were etched with 5% hydrofluoric acid for 20 seconds and 60 seconds, respectively, as recommended by the manufacturers. The Monobond N primer, which contains silane, was applied to both materials. Associating hydrofluoric acid with silane is the most effective surface treatment with which to potentiate the bond between the lithium disilicate ceramic surface and the adhesive material.[29] The silane enhances the chemical bond between the silicon-containing materials and the resinous material used for luting.[30] Both IPS e.max CAD and Vita Enamic contain silicon in their composition. Silane was not applied to the Lava Ultimate veneers because it is not recommended by the manufacturer. However, such a procedure could be performed since the Lava Ultimate has nanoceramic silica particles. In addition, silane improves the wettability of the material surface, allowing greater contact between the adhesive and the restorative material.[31,32] The manufacturer probably does not recommend silane application because the Single Bond Universal adhesive system contains silane. The exact percentage of the silane present in this adhesive is not known, but studies[33,34] have shown that it is not enough to effectively optimize the ceramic-resinous bonding, as compared with a separate application of silane.

Of the three CAD/CAM restorative materials used to make the occlusal veneers, the highest fracture resistance was obtained with the IPS e.max CAD with a 1.5-mm thickness, which was significantly superior to the Lava Ultimate and Vita Enamic veneers with a 1.5-mm thickness. Therefore, the second hypothesis was rejected.

Lava Ultimate is a nanoceramic resin material with a high rate of polymerization that has a modulus of elasticity of 13 GPa and a flexural strength of 200 MPa (manufacturer's information; 3M ESPE).[35] Vita Enamic is referred to as a hybrid ceramic, having a modulus of elasticity of 30 GPa and a flexural strength of 150-160 MPa (manufacturer's information; VITA Zahnfabrik).[36] IPS e.max CAD is a lithium disilicate ceramic with a modulus of elasticity of 95 GPa and a flexural resistance of 360 MPa (manufacturer's information; Ivoclar Vivadent).[37] In another study[9] that used a fatigue resistance methodology different from the methodology used herein, ultrathin occlusal veneers with a 0.6-mm thickness made from composite resins (Paradigm MZ100 and XR) had a higher fatigue resistance when compared to ceramic materials (IPS Empress CAD and IPS e.max CAD). According to the authors,[9] the similarity of the modulus of elasticity between composite resin (16 GPa) and dentin (20.3 GPa)[38] may play a key role in the greater fatigue resistance of composite resins. However, with the fracture resistance methodology employed in the present study, it seems that the modulus of elasticity, as well as the flexural strength, had limited influence on the fracture resistance for Lava Ultimate and Vita Enamic with thicknesses of 0.6 and 1.5 mm and for the IPS e.max CAD with a 0.6-mm thickness. For these groups, despite differences in the modulus of elasticity and flexural strength between these materials, there was no significant difference in the fracture resistance. In addition, the stronger but brittle IPS e.max CAD ceramic was more affected by reducing the thickness to 0.6 mm, and it seems that the higher flexural strength (360 MPa) of this material may have contributed to its reaching the highest fracture resistance with a 1.5-mm thickness.

In the present study, most of the fractures were repairable, except for Lava Ultimate with a thickness of 1.5 mm. As a result of its viscoelastic properties, Lava Ultimate has the capacity to accumulate the applied force on its surface and dissipate it rapidly along the tooth structure when the limit of proportionality is exceeded. This may promote catastrophic or irreparable dental fractures[39] and may account for the occurrence of a greater number of irreparable fractures in the 1.5-mm-thick Lava Ultimate veneers. However, in studies[9,13] using the fatigue resistance methodology, catastrophic failures did not occur, and cracks were limited to the restorative material when the occlusal veneers with 0.6-mm and 1.2-mm thicknesses were made with composite resins (Paradigm MZ100 and XR) and ceramics (Empress CAD and IPS e.max CAD). This methodology of fatigue resistance provides more useful results for examining the resistance of a restoration, since most the failures that occur in the oral cavity are caused by fatigue and not by a constant axial load.[9,32] The present study used the mechanical test of fracture resistance in which a constant axial load is applied to the specimens until fracture. This is a limitation of the study, since failure by constant axial load does not represent clinical reality. Despite this, this test is an important parameter for comparing the fracture resistance between different materials and restorative techniques.

Cyclic mechanical loading is an *in vitro* aging methodology that aims to submit the specimens to a cyclic load to reproduce the masticatory loads that are applied to the restorations. In the present study, teeth restored with occlusal veneers were submitted to 1,000,000 cycles with a 200-N load. In this way, approximately four years of normal functionality was simulated, since every 250,000 cycles are equivalent to one year of average mastication.[40-42] For all of the experimental groups, mechanical cyclic loading did not cause luting failure, fractures, or cracks on the veneer surface.

The present study evaluated 0.6-mm-thick veneers, which are considered ultrathin restorations. However, a study by Egbert and others[12] tested the fracture resistance of occlusal veneers with a 0.3-mm thickness using Lava Ultimate, Paradigm MZ 100, and Vita Enamic and found promising and favorable fracture resistances. Therefore, it seems that the use of thicknesses smaller than 0.6 mm could be feasible for the restoration of eroded teeth.

The transfer of laboratory results to the clinic should be done with caution, since *in vitro* studies cannot reproduce the real conditions inside the oral cavity. However, the results presented here suggest that occlusal veneers of Lava Ultimate, IPS e.max CAD, and Vita Enamic with a 0.6-mm thickness are promising candidates for the restoration of eroded teeth.

## CONCLUSIONS

- The occlusal veneers of IPS e.max CAD, Vita Enamic, and Lava Ultimate, with thicknesses of 0.6 mm and 1.5 mm, obtained fracture resistances similar to those of sound teeth.
- Ultrathin occlusal veneers (0.6 mm) appear to be a promising restorative procedure in eroded posterior teeth.

### Acknowledgement

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### Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Ethics Committee from Pontifical Catholic University of Rio Grande do Sul. The approval code for this study is 55675416.7.0000.5336.

### Conflict of Interest

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

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