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# THE FRACTURE RESISTANCE OF OCCLUSAL VENEERS FABRICATED FROM DIFFERENT MATERIALS AND THICKNESSES

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## *ABSTRACT*

**Statement of problem:** Some clinical situations require occlusal correction with occlusal veneers as a conservative treatment approach. The exact veneer thickness that provides both preservation of tooth structure and high fracture resistance for glass ceramics and resin nanoceramics is still under investigation.

**Purpose:** The objective of the current study was to evaluate the fracture resistance of occlusal veneers fabricated from two ceramic materials (IPS e.max CAD and Lava Ultimate) and two thicknesses (0.5 and 1mm) after thermocycling.

**Materials and Methods:** Forty caries-free maxillary human premolars were prepared to receive occlusal veneers. The veneers were milled from two different materials: IPS e.max CAD (group E, n =20) and Lava Ultimate (Group L, n =20). Half of each group was milled with 0.5 mm thickness ( subgroups E1& L1 n=10) and the other half with 1 mm thickness (Subgroups E2 &L2, each n=10). Each veneer was cemented using self-adhesive resin cement. All samples were subjected to thermocycling for 5000 cycles between 5±2°c and 55±2°c with a dwell time of 30 seconds in each bath and 20-seconds interval baths at ambient air. Then, all samples were individually mounted on a computer-controlled universal testing machine for fracture resistance testing. A two-way ANOVA test was used to study the effect of ceramic type, thickness, and their interactions on fracture resistance.

**Results:** IPS. emax CAD veneers with 0.5 mm thickness (440.08±78.16) had a significantly higher value than Lava Ultimate (285.14±74.44) ($p<0.001$). Lava Ultimate 1 mm thickness occlusal veneers (385.26±93.15) showed a significantly higher value than 0.5 mm ones (285.14±74.44) ($p=0.023$).

**Conclusions:** All tested occlusal veneers exhibited fracture resistance values within average normal biting forces in maxillary premolar region. IPS.emax CAD ceramic is the material of choice for high strength conservative occlusal veneers with 0.5 mm thickness.

**KEY WORDS:** Occlusal veneers, Thickness , Resin nanoceramic, Glass ceramics.

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## INTRODUCTION

Natural occlusal contacts between the maxillary and mandibular teeth might be lost due to wear, malposition, or caries. [1] The causes of tooth wear are multifaceted and include oral habits, medical diseases, and dietary practices that cause the enamel and dentin to wear off and/or erode. [2],[3] Since it affects the harmony of the musculoskeletal system, occlusal stability, oral comfort, aesthetics, and the general satisfaction of the patient with their dentition, the loss of tooth structure has been a major cause for concern. [4,5]

A thorough diagnosis, etiological factor identification, and subsequent selection of the most suitable treatment protocol are necessary for the effective management of such cases. [6] Treating these issues is difficult and complicated as removal of undamaged hard dental tissues must be done to allow space for conventional restorative materials. [7, 8] Traditional methods of treating tooth wear on posterior teeth, especially when it is advanced, may call for full-coverage crowns, ceramic onlays, and overlays. [9] Treatment concepts that propose the restoration with full crowns [10] necessitate substantial further preparation of the already compromised dentition. [11] Full crown preparations could eventually result in vitality loss and the necessity for endodontic therapy due to biological problems. This requires minimally invasive indirect ceramic restoration manufacturing and cautious pretreatment of the worn teeth. [6]

A modern restorative technique recommended for teeth with occlusal wear is the use of table-top or ultrathin occlusal veneers. When a patient has significant occlusal wear from a para-functional habit or physiological processes like erosions, occlusal veneers are the best choice to restore the occlusal vertical dimension. [12]

Nowadays a vast amount of modified and hybrid ceramic materials are available with improved mechanical properties. Compared to traditional glass ceramics, these materials exhibit greater flexural strength and fracture toughness. They allow for restorations with reduced thickness. One of these ceramics is IPS e.max which consists of a lithium disilicate glass-ceramic, but with a refined crystal size. It is a versatile material that provides an excellent combination of strength and translucency.[13]

The goal of the hybrid ceramic CAD/CAM materials is to create materials that closely resemble dentin in terms of modulus of elasticity, more easily milled than glass ceramics or polycrystalline ceramics, can be repaired intraorally, and offer superior esthetic properties. Lava Ultimate introduced by 3M ESPE, is a resin-matrix hybrid ceramic material. It consists of a highly cured resin matrix reinforced with approximately 80% by weight nanoceramic particles. The combination of discrete silica nanoparticles (20 nm diameter), zirconia nanoparticles (4-11nm diameter), and zirconia-silica nanoclusters (bond aggregates of nanoparticles) reduces the interstitial spacing of the filler particles, enabling this high nanoceramic content. [14]

The fracture resistance of all ceramic restoration is also influenced by the restoration thickness. A study by ***Sasse et al*** [15] suggested the use of a restoration thickness of 0.7 mm at fissures and 1mm at cusp tip for optimized fracture resistance of Lithium disilicate occlusal veneers.

The exact thickness of each ceramic material used for occlusal veneers is still under investigation. Therefore, this study was conducted to investigate the effect of two ceramic materials and two different thicknesses on the fracture resistance of occlusal veneers after thermocycling. The null hypothesis was that neither the ceramic material type nor the thickness would affect the fracture resistance of occlusal veneers.

## MATERIALS AND METHODS

### 1-Natural teeth mounting and preparation:

Forty natural caries-free human upper first premolars teeth were embedded parallel to their long axis using a dental surveyor in self-cure acrylic resin (Acrostone, Egypt) 1.0 mm apical to the cementoenamel junction using a custom-made rubber mold (35x35x20mm). The Ethics Committee in the Faculty of Dentistry, Ain Shams university has approved the use of human teeth.

Putty and light silicone index (DMG Silagum, Germany) was made for each tooth before preparation and was sectioned in a buccolingual direction to control tooth reduction. Half of the teeth occlusal surfaces was prepared to receive 0.5 mm thickness occlusal veneers, while the other half was prepared to receive 1mm occlusal veneers. V-shaped occlusal preparation with feather edge margin following occlusal anatomy was performed. Preparations were done using high speed hand piece and tapered with round-end diamond stone. The amount of preparation was controlled and measured by periodontal probe guided by the index as shown in Fig (1).

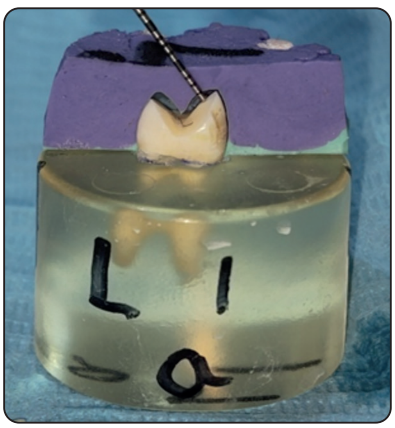


Fig. (1): Checking the amount of occlusal preparation.

**2- Computer Aided Designing/ Computer Aided milling of occlusal veneers:**

Swing 3D scanner (DOF, Korea ) was used to obtain digital impressions of all prepared teeth. After 3D-model calculation using EXO-Cad SW 2018 (Valletta 2.2), the biogeneric anatomy was used in all designed samples. Anatomic margin finding was used to trace finish lines of all scanned teeth, restoration insertion axis was selected automatically by the software. In order to standardize the thickness of the spacer in all samples, spacer values were set at 100$\mu$m. The thickness of the occlusal veneers was detected at 0.5 mm for half of the designs and 1 mm for the other half. InLab MCXL milling machine (Dentsply Sirona, Germany) was used to mill the occlusal veneers. Twenty occlusal veneers were milled from IPS e.max CAD blocks (Ivoclar Vivadent, Switzerland) (Group E), and another twenty occlusal veneers were milled from Lava Ultimate blocks (3M, Germany) (Group L). Half of each group was milled with 0.5 mm thickness (subgroups E1& L1 n=10) and the other half with 1 mm thickness (Subgroups E2 &L2, each n=10). Finishing and crystallization of E-max occlusal veneers were done according to the manufacturer's instructions. Finishing and polishing of Lava Ultimate occlusal veneers was done according to the manufacturer's instruction. Before cementation, each veneer was seated on its corresponding preparation for checking of proper seating and marginal adaptation using magnifying lens (Fig 2). The thickness of each veneer was checked using a caliber (Fig 3)

**3- Resin cementation of occlusal veneers:**

The inner surfaces of E-max veneers were etched according to manufacturer's instruction using 5% hydrofluoric acid (Bisco Porcelain Etchant, BISCO Inc. Schaumburg, USA) for 20 seconds. All etched

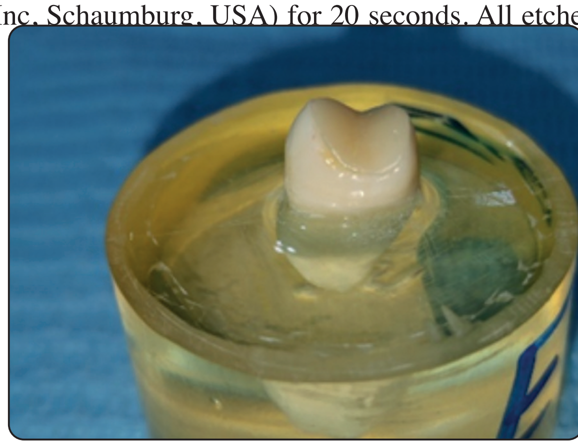

Fig. (2): Checking seating and margins of milled occlusal veneer.

Fig. (3): Checking the thickness of 0.5 mm occlusal veneer.

internal surfaces were thoroughly rinsed using water spray and dried with oil-free compressed air and then silane (Bisco silane, Bisco Inc., Schaumburg, USA) was applied to each fitting surface. Then gentle oil-free compressed air was applied on the surface for 60 seconds. The inner surfaces of Lava Ultimate restorations were cleaned with ultrasonic cleaner and dried with gentle oil-free compressed air. Then, veneers were sandblasted with aluminum oxide grain size ≤ 50 um at two bars (30 psi), cleaned with alcohol and dried with gentle oil-free compressed air. Silane was applied (Bisco silane, Bisco Inc., Schaumburg, USA) for 60 seconds followed by gentle oil-free compressed air drying.

Teeth were cleaned with ultrasonic cleaner then dried with gentle oil-free compressed air, followed by application of 37% phosphoric acid gel (30 seconds). The etched surfaces were thoroughly rinsed using water spray and dried with oil-free compressed air. Application of thin layer of bonding agent (All bond universal, Bisco Inc., Schaumburg, USA) followed by gentle oil-free compressed air drying and 20 seconds light curing were done. Automix Duolink resin cement (BISCO Inc, Schaumburg, USA) was used for cementation.

After seating of each ceramic veneer on its corresponding preparation, a universal testing machine was used to apply a standardized load of 3 kg directed toward the central groove to standardize the pressure during seating of the veneers, the excess cement was removed using a micro brush. Light curing was performed using the 3M ESPE LED (3M, Minnesota, USA. All tooth surfaces (mesial, buccal, lingual, distal, and occlusal) were exposed to light curing for 20 seconds each. The samples were subsequently stored in saline at 37°c for three days. Afterward, using a digital SD mechatronic thermocycler (SD MECHATRONIK, Germany) the samples were subjected to thermocycling for 5000 cycles between 5±2°c and 55±2°c with a dwell time of 30 seconds in each bath and 20-seconds interval baths at ambient air.

**4- Fracture resistance testing:**

Using Bluehill lite software from Instron®, a fracture resistance test was conducted. Data were collected using computer software (Instron® Bluehill Lite program), and each bonded veneer was mounted separately on a computer-controlled materials testing equipment (Model 3345; Instron Industrial Products, Norwood, Massachusetts, USA) with a loadcell of 5 kN. Samples were attached to the testing machine's lower fixed compartment. In order to achieve uniform stress distribution and minimize the transmission of local force peaks, the fracture test was performed using a compressive mode of load applied occlusally at the middle of the occlusal veneer using a metallic rod with a spherical tip (5.6 mm diameter) attached to the upper movable compartment of the testing machine and travelling at a cross-head speed of 1 mm/min. The load required to fracture was recorded in newtons. (Fig.4)

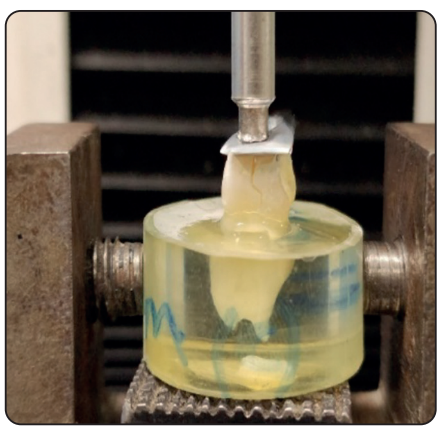

Fig. (4): Fracture resistance testing.

**5- Statistical Analysis:**

Categorical data were presented as frequency and percentage values and were analyzed using chi-square test. Numerical data were presented as mean and standard deviation values. They were checked for normality using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects were done utilizing Bonferroni correction with the pooled error term from the main ANOVA model. The significance level was set at p ≤0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

## RESULTS

### I -Fracture resistance

***a) Effect of material within each thickness***

For occlusal veneers with 0.5 mm thickness: Emax (440.08±78.16) had a significantly higher value than Lava Ultimate (285.14±74.44) (p<0.001). For 1mm veneer thickness: Emax veneers (459.13±88.94) had a higher value than Lava Ultimate (385.26±93.15) yet the difference was not statistically significant (p=0.105) as shown in table (1).

TABLE (1): Mean ± standard deviation (SD) of maximum load (N) for different materials and thicknesses

| Material | Maximum load (N) (mean±SD) | | p-value |
|---|---|---|---|
| | Emax | Lava Utimate | |
| **0.5 mm** | 440.08±78.16 | 285.14±74.44 | **<0.001*** |
| **1 mm** | 459.13±88.94 | 385.26±93.15 | **0.105ns** |
| **p-value** | **0.636ns** | **0.023*** | |

***b) Effect of thickness within each material***

Emax 1 mm thickness occlusal veneers (459.13±88.94) had a higher value than 0.5 mm ones (440.08±78.16) yet the difference was not statistically significant (p=0.636). While for Lava Ultimate 1 mm thickness occlusal veneers (385.26±93.15) showed a significantly higher value than 0.5 mm ones (285.14±74.44) (p=0.023) as shown in table (1).

### II- Mode of failure

Majority of E-max samples had cracked restorations and majority of Lava Ultimate samples had broken restorations, the difference was not statistically significant (p=0.598) as shown in table (2).

Majority of the 0.5 mm thick samples had broken restoration while most of the 1 mm thick samples had cracked restorations yet the difference was not statistically significant (p=0.287) as shown in table (3).

Different modes of failure are shown in figures (5a, b,6a &6b).

TABLE (2): Frequencies and percentages of mode of failure in different materials.

| Failure mode | | Emax | Lava Ultimate | p-value |
|---|---|---|---|---|
| **Broken restoration** | **n** | 6 | 8 | |
| | **%** | 33.3% | 44.4% | |
| **Cracked restoration** | **n** | 9 | 6 | **0.598ns** |
| | **%** | 50.0% | 33.3% | |
| **Broken restoration and tooth** | **n** | 3 | 4 | |
| | **%** | 16.7% | 22.2% | |

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)***

TABLE (3): Frequencies and percentages of mode of failure in different thicknesses

| Failure mode | | 0.5 mm | 1 mm | p-value |
|---|---|---|---|---|
| **Broken restoration** | **n** | 9 | 5 | |
| | **%** | 50.0% | 27.8% | |
| **Cracked restoration** | **n** | 7 | 8 | **0.287ns** |
| | **%** | 38.9% | 44.4% | |
| **Broken restoration and tooth** | **n** | 2 | 5 | |
| | **%** | 11.1% | 27.8% | |

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)***

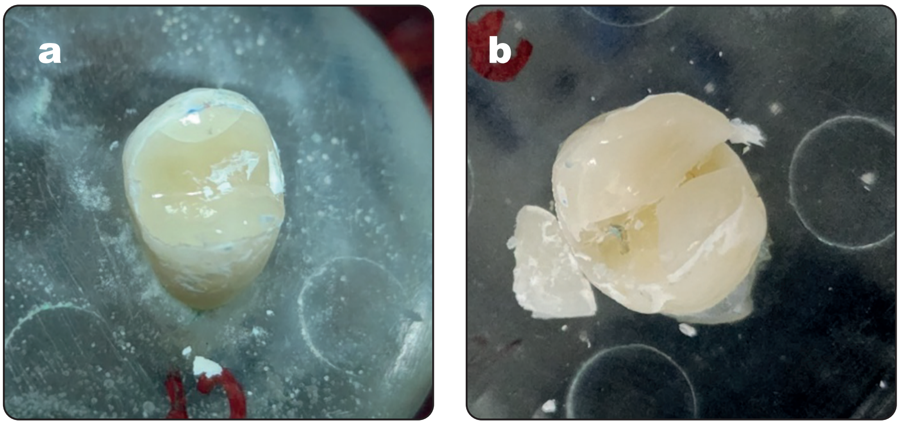


Fig. (5) a: Cracked Emax veneer, b: Broken Emax veneer.

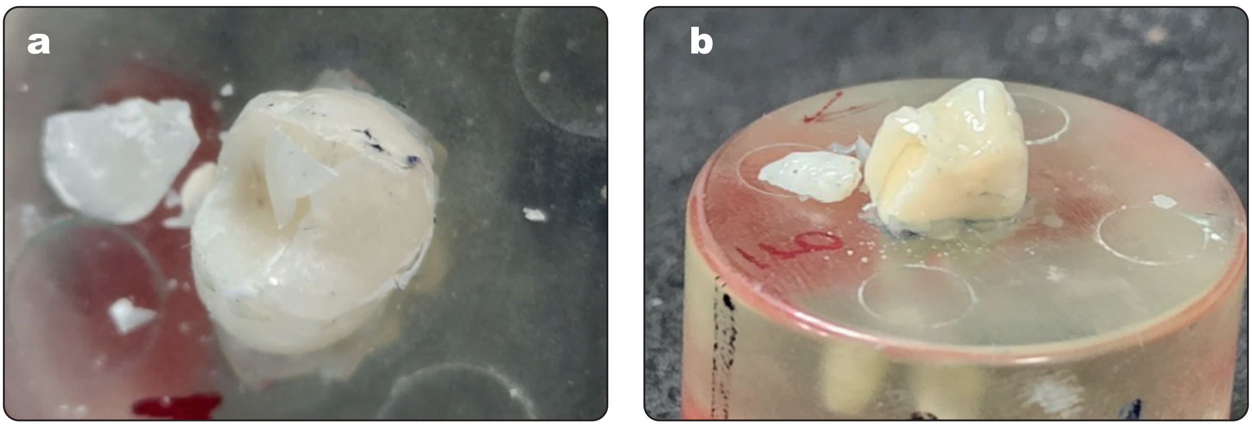


Fig (6) a: Broken Lava Ultimate veneer , b: Broken tooth and Lava Ultimate veneer

## DISCUSSION

Over the past ten years, there has been a noticeable rise in the usage of ceramic restorations that are tooth-colored. [16] Modern restorative dentistry is very interested in minimally invasive dentistry due to the invention and advancement of dependable adhesive bonding procedures and ceramic materials. For teeth and restorations to survive a long time, tooth structure preservation is essential. [17,18] In cases of significant occlusal tooth loss, partial coverage restorations, such as occlusal veneers with a reduced thickness, may be a conservative option to restore vertical dimension.

This study was conducted to investigate the fracture resistance of Lithium disilicate (IPS.emax CAD) and Resin nanoceramic (Lava Ultimate) occlusal veneers fabricated from two different thicknesses (0.5 and 1 mm) after thermocycling.

Restorative materials have often been subjected to alternating in vitro thermal stress in dental research to mimic alternating temperature stress in vivo. For 5000 cycles, the provocation temperature is primarily 5 °C for cold provocation and 55 °C for heat provocation. [19] The same cycles numbers were used by **Abou-Madina** et al in 2012 [20] , **Saridag et al** in 2013 [21] and **Bedair et al** in 2017 [22]. In this investigation, Natural human teeth were used to approximate clinical relevance. The results of this study showed that: Emax occlusal veneers with 0.5 mm thickness had a significantly higher fracture resistance value (440.08±78.16) than Lava Ultimate veneers (285.14±74.44) and 1mm thickness Emax veneers had a higher value (459.13±88.94) than Lava

Ultimate veneers (385.26±93.15) yet the difference was not statistically significant. These findings are close to ***Al Khali et al***,[1] who reported that the fracture resistance of Emax Cad occlusal veneers were higher than Polymer infiltrated Ceramic and Polymethylmethacrylate resins. They attributed their results to the microstructure of ceramics and the strengthening effect of adhesive bonding.

The microstructure of lithium disilicate contains small interlocking platelet-like crystals that are randomly oriented and provide the strength of this ceramic. Lithium disilicate crystals and the glassy matrix have different coefficients of thermal expansion, which causes tangential compressive stresses around the crystals, increasing the material's strength and causing crack deflection. In single crowns, the material has shown excellent clinical performance and survival rates. [13] The manufacturer claims that the product has gone through ten years of continuous quality testing. In these tests, it has shown a mean biaxial flexural strength of 530 MPa. [23] Also, the high fracture resistance of Emax veneers could be related to the proper etching pattern created by hydrofluoric acid, so that a stronger bond with the adhesive resin cement could be achieved. [24]

Although Lava Ultimate showed lower fracture resistance values than Emax occlusal veneers, all fracture resistance values are within the normal biting forces in the maxillary premolar region. Clinically, the normal biting force is 222–445 N (average 322.5 N) for the maxillary premolar area. During clenching, the occlusal force is approximately 520–800N (average 660 N).[25,26]

The good performance of Lava Ultimate could be related to its microstructure. Monodisperse, non-agglomerated silica (20-nm diameter) and zirconia (4-11-nm diameter) nanoparticles present in Lava Ultimate blocks create nanoclusters (0.6-10 m), which provide structural integrity and enable a large proportion of ceramic fillers to be integrated. Moreover, additional nanomers are inserted into the interstitial spaces between the particles, increasing the amount of ceramic in the final product. The nanoceramics are treated with a proprietary silane coupling agent to chemically bond with the resin matrix during the manufacturing of the blocks. According to the manufacturer of Lava Ultimate, extended heat treatment of the resin matrix results in its high strength, which is also reflected in the reported flexural strengths of 205 MPa.[14,27]

In this study, Majority of E-max samples had cracked restorations and majority of Lava Ultimate samples had broken restorations yet the difference was not statistically significant. The failures of the occlusal veneers were mostly within the restorative materials. Hence, greater veneer strength values did not result in more unfavorable tooth structure damage. According to ***Egbert et al***,[28] this improve the longevity prognosis of a restored tooth because the occlusal veneer can be simply replaced by milling an identical veneer. Failures that involve the tooth structure may necessitate elective endodontic treatment and can lead to extraction and further jeopardize of a patient's dental health. These findings also could explain the higher fracture resistance of Emax occlusal veneers.

Emax 1 mm thickness occlusal veneers (459.13±88.94) had a higher value than 0.5 mm ones (440.08±78.16) yet the difference was not statistically significant and Lava Ultimate 1 mm thickness occlusal veneers (385.26±93.15) showed a significantly higher value than 0.5 mm ones (285.14±74.44). Majority of the 0.5 mm thick samples had broken restoration while most of the 1 mm thick samples had cracked restorations yet the difference was not statistically significant. These findings are in agreement with ***Chen et al***. ,[29] It was stated that "bulk characteristics" predominate when the ceramic is thick. The primary fracture type for dental porcelains and fine-grained glass ceramics is cone cracking. The chipping and surface cracks in porcelain inlays, onlays, and veneering porcelains are caused by this cone cracking, which is independent of the substrate.[30]

As both the material type and veneer thickness affected the fracture resistance, the null hypothesis was rejected. Further investigations considering the effect of dynamic loading on fracture resistance of occlusal veneers are recommended for future studies.

## CONCLUSIONS

**Based on the findings of this research and under its limitations, the following conclusions could be drawn:**

1. All tested occlusal veneers exhibited fracture resistance values within average normal biting forces in maxillary premolar region.
2. IPS.emax CAD occlusal veneers with 0.5 mm thickness had higher fracture resistance than Lava ultimate ones of same thickness.
3. IPS emax CAD occlusal veneers with 0.5 mm thickness had nearly equal fracture resistance values as those of 1 mm thickness.
4. IPS.emax CAD ceramic is the material of choice for high strength conservative occlusal veneers with 0.5 mm thickness.
5. Lava ultimate occlusal veneers with 1 mm thickness had higher fracture strength than those of 0.5 mm thickness.

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