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Fracture Strength of Two Types of Hybrid Ceramic Posterior Occlusal Veneers with Different Thicknesses

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Abstract: ***Objective**: the purpose of this study was to investigate fracture strength of two types of hybrid ceramic posterior occlusal veneers with different thicknesses. **Materials and methods**: Eighty natural maxillary molars of comparable size and morphology will be selected. Standardization of the teeth preparations will be accomplished using a diamond saw; teeth will be sectioned horizontally, removing all coronal tooth structure 4 mm occlusal to the CEJs leaving exposed dentin centrally and peripheral enamel. Samples will be randomly divided into two groups (n=40) based on restorative materials that will be used: computer-milled hybrid ceramic (ENAMIC) and Resin Nano Ceramic (LAVA ULTIMATE). Each group will be divided into two subgroups (20 samples each) according to the type of preparation (conventional and experimental). The experimental preparation will have an additional preparation feature. Within each subgroup, specimens were subdivided into two classes (consisting of 10 specimens each n=10) based on restoration thickness (0.3, 0.6 mm). Each class will be divided into 2 subclasses (n=5) for testing the fracture resistance and the microleakage. Specimens will be stored in distilled water 37^{o}C for 7 days. Restorations will be adhesively bonded to their respective teeth for measuring fracture. **Result**: The fracture strengths (mean ± standard deviation) were 2416 ± 676, and 1777 ± 697, N for Lava Ultimate, and Vita Enamic, respectively. Lava Ultimate had significantly higher fracture strength than the Vita Enamic (p < 0.05); . No correlation between fracture strengths and failure modes was found within each material. Most specimens (48 out of 60) fractured in the restoration without involving tooth structures. **Conclusion**: The fracture strength of ultrathin occlusal veneers made from the novel ceramic hybrid matched the strength of CAD/CAM composite. The highest strength was found with the resin nanoceramic material.*

Keywords: Occlusal Veneers, Lava Ultimate, Vita Enamic

1. Introduction

The evolution of dental technologies such as CAD/CAM (Computer-Aided-Design/Computer-Aided-Manufacture) continues to expand the restorative alternatives available to the dental patient. The biocompatibility, strength and durability of indirect restorations fabricated via CAD/CAM make them attractive for anterior and posterior indications. Its scope ranges from minimally invasive anterior veneers to the newly-introduced treatment option, occlusal veneers and the so-called table tops.

In 2007 composite blocks evolved. They have superior properties compared to other forms of composite, yet inferior to ceramics. With the improvement achieved in the physical properties of blocks used, two main disadvantages of ceramics still exist. Inherent of ceramic materials causes chipping of the materials in thin sections, either during the milling process or try-in. and the high hardness relative to enamel results in wear of the opposing natural dentition. This has been a strong motive for manufacturers to develop a new entity of materials that combines strength and esthetics of ceramics and resilience and elasticity of composites elasticity of composites. In the past two years Lava-Ultimate (3M, St Paul, Minnesota, USA) and VITA Enamic (Vita Zahnfabrik, Badsäckingen, Germany) were introduced.

Selecting the appropriate indirect restoration to meet the needs of the patient and the individual tooth depends on a large variety of factors. Physical properties of each material as well as its advantages and disadvantages should be taken into consideration when determining which material is best for a particular tooth needing a particular indirect restoration [(1-3)].

Furthermore, the concepts of CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems and conservative tooth preparation seem to be converging [(5)].

Common mechanical surface treatment methods for creating micro-retentive ceramic surfaces include grinding, sandblasting and acid etching. Chemical treatment methods, such as silanization, increase the wettability of the luting agents on the ceramic surfaces. [(6)].

All-Ceramic Restorations

New composite and ceramic hybrid materials have been introduced, which can be milled at relatively thin thicknesses to accommodate conservative tooth preparations [(7)]. The CAD/CAM composite is manufactured from a restorative composite material (Z100, 3M ESPE) under optimized process conditions to obtain a high degree of cross-linking [(8)]. Thin occlusal veneers fabricated from composite resin blocks have been shown to have higher fatigue resistance than reinforced ceramics [(9, 10)]. A recent study showed that the thickness of occlusal veneers made with CAD/CAM composite (3M Paradigm MZ100, 3M ESPE, St Paul, MN) or resin nanoceramic (3M Lava Ultimate, 3M ESPE) can be decreased to 0.3 mm without affecting the fracture strength [(11)]. A new CAD/CAM ceramic hybrid material has been developed by infiltration of a polymer into a porous ceramic network (Vita Enamic, Vident, Brea, CA, USA). The majority volume of the VITA Enamic block is made up of the exact same material as the VITABLOC predicate; feldspar. The remaining volume of the block is made up of resin. This microstructure, polymer-infiltrated ceramic network, is reflected on the material properties having mechanical properties between porcelains and resin-based composites [(12)]. The resin nanoceramic, according to the manufacturer, is neither a composite nor a pure ceramic, but a mixture of both and it primarily consists of ceramics [(13)]. This polymer-infiltrated ceramic network material has a microstructure similar to a natural tooth and has mechanical properties that fall between those of porcelains and resin composites [(14)]. This material is a potential candidate for ultrathin occlusal veneers.

Bond strength is obtained from the load at failure divided by the cross-sectional area of the bonded interface, and is referred to as the "nominal" or "average" bond strength values, but this is only valid if the applied load is equally distributed throughout the entire bonded interface [(15)] . Shear bond strength tests have been widely used, mainly because of their relative simplicity when compared to tensile bond strength tests, in which it is difficult to align the specimen in the testing machine without creating deleterious stress distribution.

Advantages in shear tests include ease of specimen preparation and simple test protocol. However, problems related to the validity of obtained measurements started to arise as cohesive failures in the substrate were frequently observed with new adhesives that yield improved bond strengths. Although some authors speculated that the bonding had surpassed the cohesive strength of the substrate with no further need for improvement, the actual conclusion was that this test had turned out to be unsuitable to determine the true strength of a bonded interface [(16)].There have been few publications about occlusal veneers and little studies that compared the new polymer-infiltrated ceramic network material with composite-based CAD/CAM materials.

The objective of the present study is to compare weather the fracture strengths and failure modes of occlusal veneers fabricated from resin nanoceramic (3M Lava Ultimate) is better than or equal to ceramic hybrid (Vita Enamic) blocks under vertical compressive loading.

2. Material and Methods

Tooth preparation:
Eighty extracted human maxillary molars were collected from out patient hospital of national research center and out patient hospital of Minia University. Careful examination with 2.5× magnifying loupes [Keeler Ltd., UK] to ensure they were free from any caries, defects and cracks. Teeth were selected so that the mean measurement of the bucco-palatal width between the teeth varied by no more than 2.5%, also they had comparable crown and root dimension to ensure a similar modulus of elasticity. An ultrasonic scaler was used to remove calculus deposits, debris and soft tissue remnants. [(17)]

Standardized tooth preparations replicating a worn occlusal table were accomplished using a diamond saw** (Fig.1&2). Using a digital caliber to measure 4mm (15) occlusal to CEJ the remaining entire coronal structure was removed sectionally perpendicular to the long axis of the tooth using a diamond saw Leaving a flat area of exposed dentin and peripheral enamel. Indexing notches were created on the mesial and distal finish lines with a high-speed round-ended diamond rotary bur*** . The prepared teeth were visually examined and discarded if any damage was found.

Figure 1 & 2: Extracted tooth specimen mounted in acrylic base the prepared specimen showing indexing notches and demonstrating intact enamel and dentin

Factorial design
The prepared teeth were then randomly assigned to two groups based on the two restorative materials to be tested:
1) Vita Enamic (Vident, Brea, CA). (VE)
2) 3M Lava Ultimate (3M ESPE). (LU)

Each group was divided into two subgroups (20 samples each) according to the type of preparation either conventional and represent as subgroup 1 (n=20) or experimental which represent as subgroup 2 (n=20). The experimental preparation will have an additional preparation feature. Within each subgroup, specimens were subdivided into two classes (consisting of 10 specimens each) based on restoration thickness (class I 0.3mm thickness) and stand for it letter (A) while class II 0.6 mm thickness and stand for it letter (B). Teeth will be subjected to fracture resistance F for all samples with different thicknesses and preparation method.

Forty of the selected teeth were randomly chosen and mounted in a custom made gypsum cast made with a centralized hole to mount the teeth. (Fig.3). The surveying platform of a dental surveyor is used to adjust the parallism of the custom made gypsum cast with hole just below the surveying arm of the surveyor. A high speed contra angel (NSK; Tokyo; Japan) was attached to the surveying arm with certain angle 70^o to create the same finish line (bevel) for all the chosen experimental teeth. This angel 70o was determined using a protractor to mount the contra angel as shown in (Fig.4).

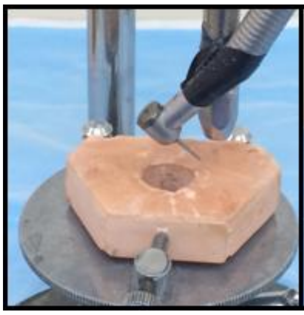

Figure 3

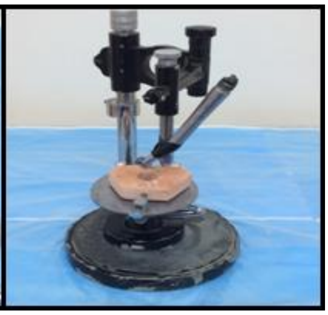

Figure 4

Scanning of the prepared samples

A standardized occlusal form was created by trimming the cervical structure from an anatomic ready made denture tooth [Ivoclar Vivadent, Amherst, NY] to within 0.3 or 0.6 mm of the central fossa measured by caliber (Fig.5).

Which were positioned on the prepared tooth specimens during the ‘‘occlusion’’ scans (Fig.6). Using Sirona Inlab MCX5 milling machine (5 axis) [Sirona Dental Systems GmbH, Bensheim, Germany] scans of each prepared tooth surface were obtained as well as secondary scans of each specimen bearing the standardized occlusal form positioned in best agreement with its perimeter outline and axial rotation.

Figure 5: Measuring the central fossa by caliber

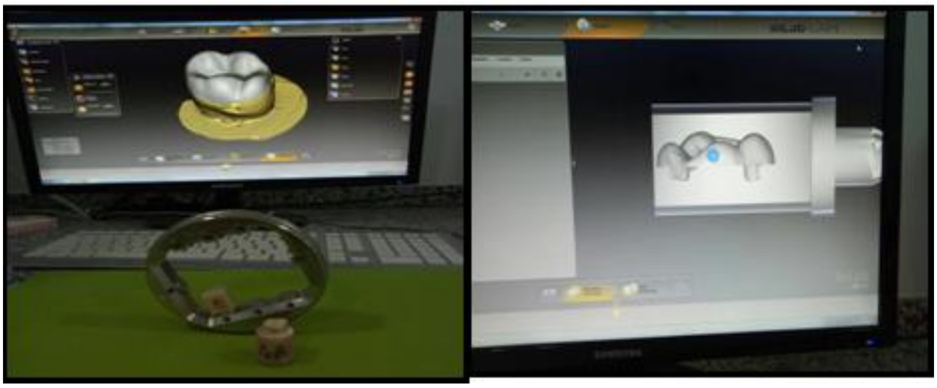

Figure 6: Scans of prepared specimen with and without occlusal form and scanning positioned on specimen

Restoration fabrication

Using the virtual design tools within the software, the occlusal cervical dimensions were adjusted to the prescribed thicknesses assigned to each test group. Standard groups of 0.3 mm thickness were constructed from Vita Enamic blocks (VE1A) and Lava Ultimate blocks (LU1A) with a minimal thickness of 0.3 mm (measured from the depth of the central fossa to the preparation surface), while groups of Vita Enamic (VE1B) and Lava Ultimate (LU1B) were also designed of 0.6 mm minimal thickness. Groups of Vita Enamic blocks (VE2A) and Lava Ultimate blocks (LU2B) were designed with modified bevel with minimal thickness of 0.3 mm, and groups Vita Enamic (VE2A) and Lava Ultimate (LU2B) were designed also with modified bevel of 0.6 mm minimal thickness measured from central groove using dental caliber.

Milling sprue locations were designated on the distal surface of each final proposal, and restorations were computer milled from either Vita Enamic or from Lava Ultimate restorative materials for all the groups.

The occlusal veneer restorations were milled to their prescribed central fossa thickness of 0.3 or 0.6 mm. After milling, the sprues were trimmed with a high-speed diamond bur [ZR 850 FG.01, Komet USA, Rock Hill, SC, USA] removal was done using coolant with slight pressure exerted. The occlusal veneers were checked for defects and proper fit.

3. Finishing and polishing

Results

Vita Enamic was finished and polished using VITA ENAMIC polishing set technical.. Sof-Lex polishing discs were used for pre-polishing the medium grain (M) and very fine grain (SF) types. Using the pink polishers of the VITA ENAMIC polishing set at (7,000 – 10,000 rpm) while using water as a coolant. High-gloss polishing with the grey diamond-coated polishers of the VITA ENAMIC Polishing Set (5,000 - 8,000 rpm) with slight pressure was exerted. Lava Ultimate occlusal veneers were finished and polished using Sof-Lex™ discs and diamond polishing paste with silicone impregnated rubber cup.

Cementation

Before the occlusal veneers were cemented, the inner surfaces were air-abraded per manufacturer specifications using 50µm of aluminum oxide at 1.8 bar of pressure, [Basic Quatro 230/240,Renfert Gmbh] cleaned with alcohol, and dried with oil-free pressurized air. The enamel and dentin were etched with 37.5%phosphoric acid [Total etch, Ultradent, South Jordan, UT, USA] for15 s. The prepared teeth were rinsed and blot-dried to avoid desiccation. The occlusal veneers were cemented with a self-adhesive dual-cure resin cement [RelyX Unicem, 3M ESPE]. The manufacturer's instruction includes an option of applying etchant to the tooth. A uniform vertical seating pressure of 6 N was applied using a custom-fabricated seating device (Fig.7), and residual cement was removed using universal carver. Buccal, lingual, mesial, and distal surfaces were light-polymerized using light cure each, for 20 sec [SmartLite Max LED, Dentsply, York, PA,USA]. The restored teeth were stored in distilled water at room temperature for 7 days prior to testing.

Fracture Strength Testing

After 7 days of storage, the restored teeth were placed in a universal testing machine and subjected to an increasing vertical load until fracture. All samples were individually mounted on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software). Samples were secured to the lower fixed compartment of testing machine by tightening screws. Fracture test was done by compressive mode of load applied occlusally using a metallic rod with round tip (5.6 mm diameter) attached to the upper movable compartment of testing machine traveling at cross-head speed of 1mm/min. with tin foil sheet in-between to achieve homogenous stress distribution and minimization of the transmission of local force peaks. The load at failure manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using computer software [Bluehill Lite Software Instron® Instruments]. The load required to fracture was recorded in Newton. The fracture strength was the highest recorded load value before an at least 25% drop in load was observed.

Statistical analysis:

One-way analysis of variance (ANOVA) followed by Scheffe's post hoc test was used to statistically analyze the difference in failure load among the two materials groups. After fracture, the specimens were examined under a stereomicroscope with a charge-coupled device (CCD) camera [SZX16 andUC30, Olympus, Tokyo, Japan.]. Data will be collected and tabulated as means and standard deviations (SDs). Statistical analysis will be performed using SPSS® version 20 (Statistical Package for Social Sciences version 20, SPSS Inc, Chicago, IL, USA).

Failure mode

After fracture, the specimens were examined under stereomicroscope with a charge-couple device (CCD) camera. The mode of failure were categorized as the following:

Mode I, fracture in the restoration only; Mode II, fracture of the restoration and enamel; or Mode III, fracture of the restoration, enamel, and dentin. The correlation between the fracture load and mode of failure within each material was tested using Spearman's rank-order correlation.

Figure 7: Viewing the samples for the pre-indented mid axial surface

The fracture strengths (Table 2) were significantly different between the two groups (one-way ANOVA ,p < .(0.002The Lava Ultimate (resin nanoceramic composite material) occlusal veneer showed significantly higher fracture strengths than the restorations made with Vita Enamic (Scheffe's post hoc test ,significance level 0.05).

Statistical significant difference in fracture strengths was found in occlusal veneers made Vita Enamic and Lave Ultimate (ceramic hybrid material).Fig. 12 shows the three modes of failure. The numbers of specimens for each failure mode and material type are shown in Table (1&2).

In the 80 specimens (all materials combined), 58 fractured in the veneer material (Mode I), and eight of these 58 had a complete delamination of the fractured restoration. Twelve specimens fractured in the restoration and enamel (Mode II). Ten specimens fractured in the restoration, enamel, and dentin (Mode III). Of these four specimens, three did not result in a delamination of the restoration. Spearman's rank-order correlation coefficient for the bivariate set of data did not show significant correlation between fracture strength and failure modes within each material.

Table 1: Vita Enamic

	Specimen label	Maximum Load (N)
1	Vita Enamic 0.3 E'out preparation	770.69
2	Vita Enamic 0.3 With	890.36
3	Vita Enamic 0.6 E'out preparation	773.57
4	Vita Enamic 0.6 With	899.55

Table 2: Lava Ultimate

	Specimen label	Maximum Load (N)
1	Lava Ultimate 0.3 E'out preparation	958.2
2	Lava Ultimate 0.3 With	1252.68
3	Lava Ultimate 0.6 E'out preparation	1035.67
4	Lava Ultimate 0.6 With	458.32

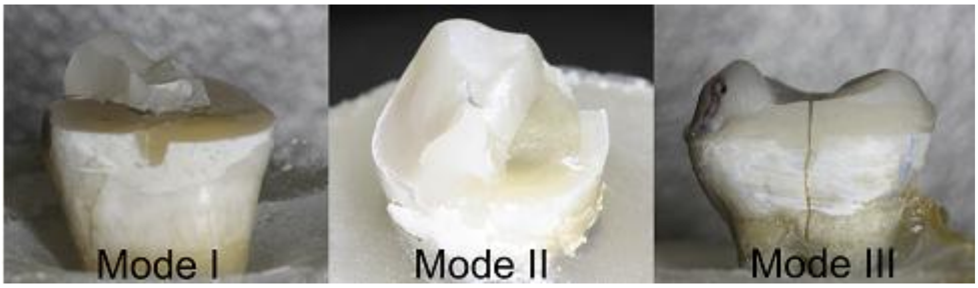

Figure 12: Failure modes: Mode I, failure of Restoration; Mode II, failure of Restoration and Enamel; and Mode III, failure of Restoration ,Enamel, and Dentin

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. One-way ANOVA followed by pair-wise Tukey's post-hoc tests were performed to detect significance between all groups. Student t-test was done between subgroups. Statistical analysis was performed using Graph-Pad InStat statistics software for Windows (www.graphpad.com). P values ≥0.05 are statistically significant in all tests.

Fracture resistance results measured in Newtons (N) showing mean values and standard deviations (SD) for both ceramic groups as function of preparation designs and thickness after mechanical cyclic loading are summarized in table (3) and graphically represented in figure (13).

Table 3: Fracture resistance (Mean±SD) for both ceramic groups as function of preparation designs and thickness after mechanical cyclic loading

Variables		Preparation design			
		Conventional		Experimental	
		0.3 mm	0.6 mm	0.3 mm	0.6 mm
Ceramic group	Vita Enamic	770.69± 36.79	773.57± 36.93	890.36± 42.51	899.55± 42.94
	Lava Ultimate	958.2±4 5.75	1035.67± 49.45	1252.68± 59.81	458.32± 21.88
t-test	P value	0.0006*	<0.0001*	<0.0001*	<0.0001*

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

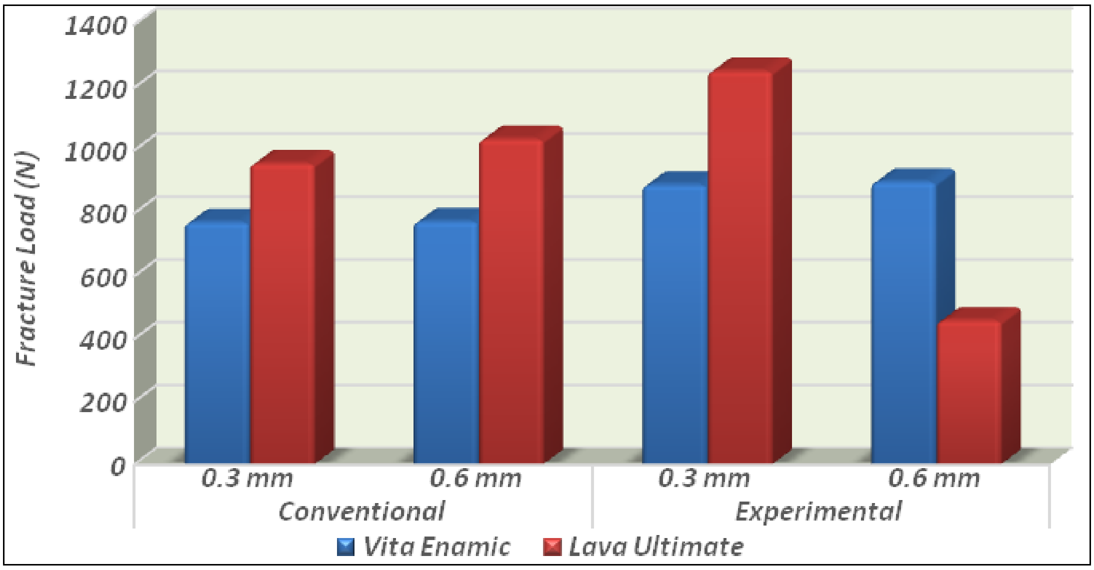

Figure 13: Column chart showing fracture resistance results mean values for both ceramic groups as function of preparation designs and thickness after mechanical cyclic loading

4. Discussion

Preservation of tooth structure is a driving force in restorative dentistry. From a biomimetic perspective, the conservation of tooth structure is paramount in maintaining the subtle equilibrium between biologic, mechanical, functional, and esthetic parameters. It is clearly beneficial to keep the pulp alive and prevent endodontic treatment and the need for posts and cores, because these more invasive approaches violate the biomechanical balance and compromise the performance of restored teeth over time. [17]

As quantified by Edelhoff [2] preparations with deep shoulders and chamfers, as required for complete coverage crowns in the1970s and 1980s, have been strongly associated with an increase in microleakage and pulpal complications. When compared to bonded restorations, metal ceramic complete coverage crowns are also associated with more gingival inflammation and secondary caries.

Partial coverage preparations with reduced macroretentive geometry, such as onlays and partial coverage ceramic crowns, have been reported to remove half the amount of tooth structure compared to a complete coverage metal ceramic crown. With survival rates of 88.7% after 17years and 84% after 12 years, porcelain adhesive inlays and onlays had emonstrated long-term reliability. As a result, their range of indications has been increased, including treatment of advanced erosion and stabilization of teeth with cracked tooth syndrome. [18]

The benefits of decreasing retentive features of tooth preparations could be increased by the translational application of principles used in treatment with anterior porcelain laminate veneers, hence the proposal for posterior "occlusal veneers"(thin onlay/overlay with non retentive design). Such restorations could potentially compete with gold onlays/overlays. Occlusal veneers are extracoronal restorations requiring a simpler and more intuitive preparation driven by interocclusal clearance and anatomical considerations. [19]

Molars of comparable crown size and root dimensions were used, allowing similar dimensions of crowns constructed with CAD/CAM technology and a similar clinical modulus of elasticity. Extracted human teeth were used in this investigation to represent better the clinical situation. [11] This replicated a clinical situation of severe tooth wear, in which rehabilitation would be the proper treatment.

For samples standardization, a biogeneric reference mode in the Cerec software 4.3.1 was used, so that each artificial crown is designed and milled as an exact replica of the unprepared anatomy. An effort was made to standardize preparations with the use of putty index before preparation.

Several factors influence the fracture resistance of all-ceramic restorations, such as microstructure and fatigue of the ceramic material, fabrication technique, the final preparation design and the luting method. [18-20] Tooth preparation was performed according to preparation guidelines for partial coverage restorations stated in the literature which resulted in less loss of tooth structure than conventional preparation designs for partial-coverage restorations with retentive form. [10, 15]

To imitate rehabilitation in case of severe occlusal abrasion the preparation design was chosen within dentin with a finish line within enamel. [16] Finish line design was a straight beveled finish line to evaluate a possible influence of the marginal preparation design on the fracture resistance.

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. 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 thin occlusal veneers. [8, 14&16]

In complex multilayered restorations, such as cemented ceramic restorations, several factors contribute to the mechanical behavior of the restoration/tooth system. The intrinsic strength of each component of the system (i.e., tooth, adhesive system, luting cement layer, and restoration), the thickness of the restorative material, the ratios of elastic moduli between the restoration material, the luting cement and dentin, and finally the quality of the adhesive interface between these layers interms of bond strength and presence of micro or nanoleakage are all factors that play a role in the behavior of such restorations. [16, 20]

Lava™ Ultimate CAD/CAM Restorative was used because of their modulus of elasticity (12.77 GPa) [21] similar to that of dentin (approximately18.5GPa) [22] and they have short laboratory steps. A strict adherence to the bonding protocols for each ceramic material used was followed according to the manufacturer's recommendations in order to eliminate variables during bonding procedures. The main interest of the present research was directed towards evaluating the fatigue resistance of Cerec occlusal veneers. Fatigue resistance were chosen in this study as they are among the critical factors that determine the success and longevity of a restoration [16]. To simulate conditions that are close as possible to the clinical situation the dynamic fatigue was evaluated in a universal testing machine [23].

Despite of their many advantages ceramics are brittle materials. Subcritical crack propagation can lead to catastrophic failure [24]. Testing a ceramic's fracture resistance in vitro is important before its clinical application. Static loading to fracture is a test widely used that can give an indication of whether a material and a type of restoration can be considered as viable clinical option. However, it can only show the strength of a restoration immediately after bonding and most likely it shows values of fracture resistance that are not indicative of the long-term success of the restoration. In the mouth, restorations are loaded during their lifetime with millions of cycles which can cause a significant reduction in the strength of the material due to fatigue.[14, 21] All ceramic restorations can be subjected to fatigue testing from 10,000 cycles to 1,200,000 cycles. [15]

Chewing force has a significant influence on the fracture resistance of all-ceramic restorations. Higher biting loads obtain on molar teeth and the measurable in vivo masticatory force in this region range between 8 to 880 N. The 150 N in the universal testing machine used is a good clinical approximation [16].

This may be due to the fact that as the bevel finish line approaches parallelism with the path of insertion of the restoration, the thickness of the space between the bevel finish line and the restoration approaches to minimum value, also bevel finish line helps to reduce the inherent defects in the cementation allowing for better escape of excess cement and better seating of the restoration.

We found that the occlusal veneers made with the novel ceramic hybrid (Vita Enamic) were lower in fracture strength under vertical loading with a resin nanoceramic composite material (Lava Ultimate). The Lava Ultimate is a highly cross-linked particle-reinforced composites, while the Vita Enamic has resin infiltrated into a sintered ceramic structure. The sintered ceramic structure is porous with a composition similar to feldspar ceramic enriched with aluminum oxide [16]. In our study, neither type of material design ensured superior fracture properties. However, within the composite types, advancements in nanotechnology, coupling agent and heat treatment of the resin matrix may have contributed to improved strength values for the Lava Ultimate material. The Lava Ultimate blocks contain mono disperse, non aggregated, and non agglomerated nanoparticles of silica (20-nm diameter) and zirconia (4-11–nm diameter) forming nanoclusters (0.6-10 µm) that give structural integrity and allow a high proportion of ceramic fillers to be incorporated.

In this study, the mean fracture loads for the different tested groups were beyond the mean reported maximum masticatory forces. Therefore, it can be assumed that all the tested specimens could withstand the maximum intraoral posterior masticatory forces.

According to the previous discussion, our results supported the hypothesis that occlusal veneers could be a viable option for the treatment of occlusal erosion or attrition instead of complete coverage crowns or onlays.

Within the limitations of this study, the following conclusions were found:

1) Occlusal veneers were found to be a successful mean of restoring erosive or attrite posterior teeth regarding fatigue resistance
2) All tested occlusal veneers designs with both materials proved to wisthstand normal and parafunctional masticatory forces.

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