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FRACTURE RESISTANCE OF OVERLAYS OF UPPER PREMOLARS RESTORED BY TWO TYPES OF PRESSABLE CERAMICS

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ABSTRACT

INTRODUCTION: There is a lack of scientific evidence about the fracture resistance properties of the newly introduced pressable type zirconia-reinforced lithium silicate when partial coverage is indicated for upper premolars.
OBJECTIVE: The aim of the study is to evaluate the fracture resistance and fractographic analysis of lithium disilicate and zirconia-reinforced lithium silicate used in overlays.
MATERIALS AND METHODS: Twenty-six duplicated epoxy resin dies were prepared following overlay preparation guidelines. The specimens were divided into two groups to be restored with lithium disilicate (IPS e.max Press) or zirconia-reinforced lithium silicate (Vita Ambria) (n=13 each). Cemented overlays were subjected to thermomechanical fatigue, and the load to fracture was tested by using a universal testing machine. The normality of the fracture resistance was checked using the Shapiro–Wilk test and Q–Q plots.
RESULTS: when comparing overlays restored with lithium disilicate and those restored with zirconia-reinforced lithium silicate, the comparison was statistically significant. Group of overlays restored with zirconia-reinforced lithium silicate showed higher mean fracture load of 1218.69.
CONCLUSIONS: The newly introduced zirconia-reinforced lithium silicate had higher fracture resistance than did the lithium disilcate and could be an alternative for partial coverage restoration.

KEYWORDS: Fracture resistance, Lithium disilicate, Zirconia-reinforced lithium silicate, partial coverage restorations.
RUNNING TITLE: Fracture resistance of two ceramic materials in overlays.

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INTRODUCTION

Dental ceramics-restored partial coverage preparation designs could be viewed as a breakthrough in modern dentistry, aligning with the recently developed ideas of biomimetic dentistry, which fundamentally upholds the belief that the best tooth restoration is one that “mimics life." Furthermore, the primary objective of the innovative minimally invasive dentistry trend has been achieved by partial coverage concepts (1). Overlays are frequently employed as an alternative to full coverage designs, particularly in the premolar region (2).
Lithium disilicate glass ceramics (LDS) have achieved appropriate agreement despite the introduction of several types of dental ceramic materials in recent years for all kinds of indirect restorations. This is because of their clinically relevant fracture resistance, which can be attributed to the highly filled glass matrix created by the shape and volume of the crystals impeded in the matrix as well as the increase in the crystalline content to about 70% (3). . Excellent clinical and scientific data are currently available for all restorations made with this material (4).
In order to increase the mechanical characteristics and biocompatibility of a lithium metasilicate glass ceramic matrix, 10% zirconium dioxide particles are homogeneously mixed into zirconia-reinforced lithium silicate glass ceramic materials (ZLS), which have recently been launched to the dentistry market (5). The use of tetragonal zirconia fillers, which produces a mechanism of crack propagation stoppage, is credited with improving the mechanical behavior (6). While a number of studies have been carried out to assess the fracture resistance of CAD/CAM ZLS restorations, none have assessed pressable ZLS (7, 8).
The probability for catastrophic fracture is the curse of brittle ceramic dental materials. The harmful process of forming new surfaces inside a body is known as fracture. Fracture often happens at loads

higher than a material's elastic limit; this stress is known as a material's fracture resistance (FR) (9).
The aim of this in vitro study is to compare FR of lithium disilicate overlays used to restore maxillary premolars with zirconia-reinforced lithium silicate. The null hypothesis is that there is no significant difference in the fracture resistance of zirconia-reinforced lithium silicate and lithium disilicate overlays.

MATERIALS AND METHODS

One maxillary premolar extracted for orthodontic purposes were inspected and checked to be caries, cracks and restoration free. The tooth was kept hydrated during the experimental procedures by immersion in saline solution (10).

Grouping

A total of twenty-six epoxy resin dies were divided into two groups according to the type of restorative material used: Group A: Overlay cavity preparation design restored with LDS (IPS e.max Press). Group B: Overlay cavity preparation design restored with ZLS (Vita Ambria).
Overlay preparation (Fig.1a): The occlusal anatomy was followed in order to reduce the buccal and palatal cusps in accordance with the ceramic MOD inlay requirements (11, 12). The reduction dimensions were achieved with a tapered flat end diamond bur (ISO 171/016, TF-21, Mani, Japan) of 1.5 mm for the buccal (nonfunctional) cusp and 2 mm for the palatal (functional) cusp. The mesial and distal boxes measured 1 mm from the pulpal floor to the gingival seat, whereas the occlusal box measured 2 mm from the cusp tip to the pulpal floor. Using a flat-end conical diamond bur (ISO 171/016, TF-31, Mani, Japan), the divergence angle (12˚) was created, with the isthmus parts extending for one third of the bucco-palatal dimension. The finish line on the palatal cusp was chamfer located 1 mm from the occlusal contact on the functional cusp and was extended to meet the mesial and distal boxes. All the measurements were made using a calibrated periodontal probe, and the internal line angles and the margins of the preparation were rounded and finished (13).
The epoxy resin dies were made with addition silicon impression material (Coltene/Whaledent AG, 9450 Altstatten, Switzerland) and silicon molds. Following mixing, the prepared natural tooth was inserted into the material-filled 20 mm-diameter plastic cylindrical container. The native tooth was extracted once the material had had time to solidify. Twenty-six silicon molds were created by repeating this process (13).
In order to prevent the entrapment of air bubbles, the base and catalyst of the epoxy resin material (solvent-free transparent epoxy resin; CMB Intl, Egypt) were combined in an auto mixing equipment (200 r/min) and then poured into the silicon molds under vibration. For 48 hours, the epoxy resin dies were let to set completely (Fig.1b) (13). After inspecting the epoxy resin dies for surface flaws using magnifying loupes (3×), bases made of epoxy resin were built to hold the dies during the fracture resistance and cyclic loading tests. The base was formed by a plastic cylinder that held the epoxy resin material, and the epoxy resin die was positioned in the middle of the cylinder until the epoxy resin was fully set (13).
Wax patterns were created using digital impressions in order to facilitate the production of the ceramic restorations. Using an intraoral scanner (CarestreamCS3700, Carestream Dental LLC, Atlanta, GA, USA), each die was sprayed with Cerec Optispray (Sirona dental systems GmBH, Germany). The continuous scan process began with the occlusal surface of the die and proceeded to scan each die's proximal surfaces in turn, alternating between bucco-palatal movement (14). Using computer-aided design tools, digital designs for the wax patterns were created (Fig.2). The designs were produced using a 5-axis milling machine (Ceramill Motion 2 - Amann Girrbach AG, Austria) by dry milling them in CAD/CAM wax blanks (Super Green wax, Natura DMAX, Daegu, Korea) (15).
Wax patterns of the overlays were invested with investment material (Bellavest T, BEGO, Germany). Following the manufacturer's instructions, LDS ingots were pressed and the restorations were built using a Firing and Pressing Furnace (Programat EP 3010; Ivoclar Vivadent, Schaan, Liechtenstein) at 850˚C for 60 minutes. In addition, ZLS ingots were pounded and the restorations were made in the same furnace for 25 minutes at 880˚C.
Following the process of divesting and separating the restorations, they were ready for cementation. To do this, the fitting surfaces of the restorations were etched for 90 seconds using 9.5% hydrofluoric acid (Bisco, Schaumburg, Illinois, USA). Following this, a layer of porcelain bonding resin (Bisco, Schaumburg, Illinois, USA) and silane coupling porcelain primer (Bisco, Schaumburg, Illinois, USA) were applied. Dual cure resin cement (BisCem, Bisco, Schaumburg, Illinois, USA) was used to lute ceramic overlays (Fig.3) (16).
A customized mastication simulator was used to subject specimens from each group to cyclic loading at a frequency of 2 Hz and a force of 49 N for 50,000 cycles. This represents conditions that would be encountered in a clinical setting for roughly three to twelve months (17). The palatal (functional) cusp was to be the starting point of contact for an antagonist made of stainless steel, which represented the opposite cusp (17). The samples were then thermocyclically treated (500 cycles, 5-55˚C, 30 s

dwell time/cycle) (18). In order to eliminate any specimens from the fracture resistance testing process, all specimens were visually inspected using a light stereomicroscope (SZ1145TR, Olympus Japan) at 5- and 10-fold magnification in order to detect any fractures or restoration debonding.

Load-to-fracture testing was performed on each specimen using a universal testing machine (5 ST, Tinius Olsen England 2018). Applying the compressive stress axially at a crosshead speed of 1 mm/min, a 4 mm diameter stainless steel sphere in the device's upper compartment made contact with each specimen's occlusal surface center (19). The load was progressively increased during the testing process until the program recorded an abrupt, dramatic drop in force, which was followed by failure. The term "fracture load" refers to the highest load (measured in Newtons) that was recorded prior to the force's magnitude decreasing (20).

Burke's classification (21) was used to categorize each specimen's manner of failure, which was as follows: Types I, II, III, IV, and V represent minor, moderate, half-lost, and severe fractures of the crown and/or tooth, respectively. Type III represents a fracture through the midline or half of the crown is lost or displaced. Furthermore, it was seen that there were fractures, chips, delaminations, and catastrophic failures.

Statistical analysis

The normality of the fracture resistance was checked using the Shapiro-Wilk test and Q–Q plots, and the resistance was found to be normally distributed. The data are presented mainly as the mean, standard deviation and 95% confidence interval (CI). The mode of fracture was presented as the frequency and percentage. All tests were two tailed, and the level of significance was set at a *p* value ≤0.05. The data were analyzed using IBM SPSS, version 23 for Windows (Armonk, NY, USA).

RESULTS

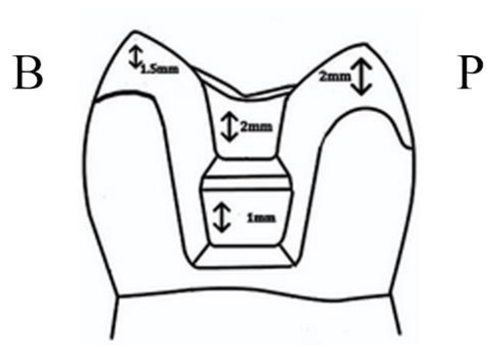
A comparison of FR between the two groups is shown in Table 1, which shows the mean± standard deviation for each group according to the 95% confidence level, medians and minimum and maximum values. Group A (E-max) has a mean FR of 1033.38± 83.13 N, while group B (Vita Ambria) has higher mean FR value of 1218.69± 87.30 N. The median of group A is 997.00, while that of group B 1232.00.When group A was compared to group B, it was statistically significant (p <0.0001*).

A comparison of the mode of fracture between the two study groups (Fig. 4), which shows the number of samples located at each type of Burke's classification. For group A the percentage of type I is 7.7%, type II is 0%, type is III 0%, type IV is 15.4% and type V is 76.9%. For group B the percentage of type I is 30.8%, type II is 30.8%, type III is 0%, type IV is 15.4% and type V is 23.1%. These results are statistically significant (*p*= 0.033*).

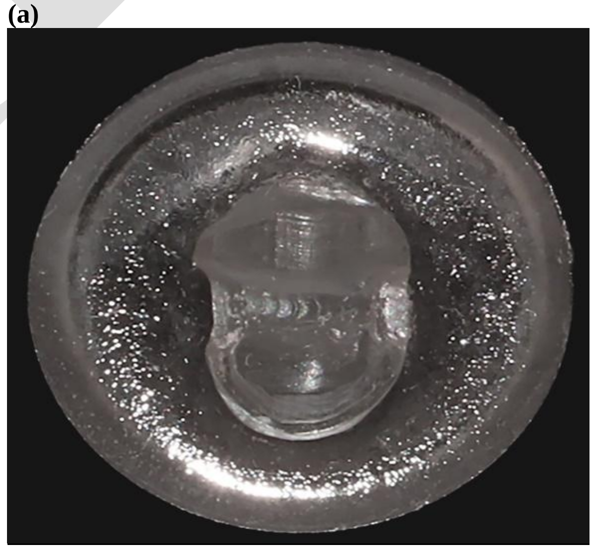
Table 1: Comparison of fracture resistance (N) among the study groups

	Overlay	
	E-max (n=13)	**Vita Ambria (n=13)**
Mean	1033.38 ± 83.13	1218.69 ± 87.30
95% CI	983.15, 1083.62	1165.94, 1271.45
Median	997.00	1232.00
Min – Max	901.00 – 1170.00	1013.00 – 1332.00

*Statistically significant difference at *p* value≤0.05



(a)



(b)

Figure 1: a shows the overlay preparation, 1b shows the epoxy die.

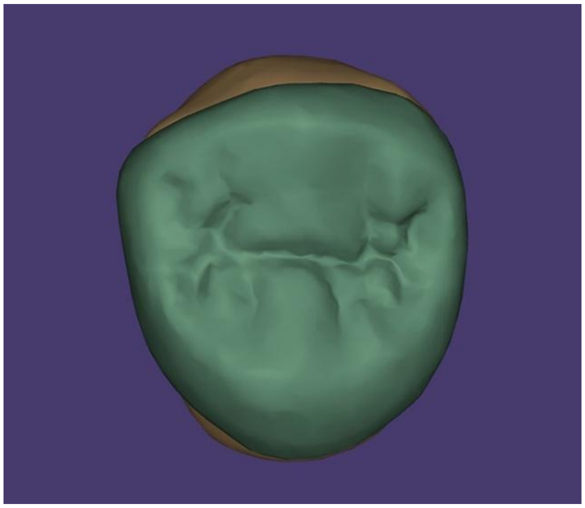


Figure 2 : showing the wax pattern design for the overlay preparation.

Figure 3 : cemented restoration on the epoxy resin die.

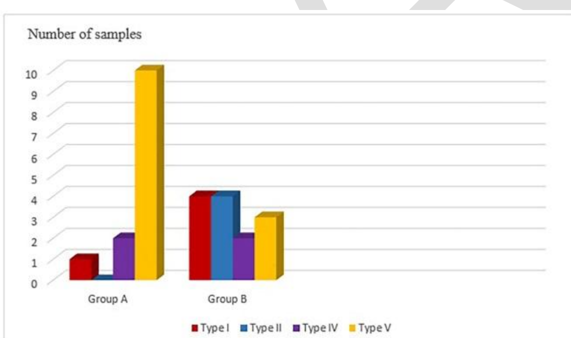


Figure 4 : A bar chart of each Burke's classification score, with color-coded bars representing the number of samples in each of the study groups.

DISCUSSION

The purpose of this study was to compare FR of IPS e.max Press, possibly the best ceramic pressable material available, to that of Vita Ambria, a recently developed material.

Because human natural teeth exhibit a wide range of dimensions that could have an impact on the ultimate results of the restorations that were created, epoxy dies were used for the experimental procedures (22). Consequently, a single maxillary first premolar was extracted in compliance with the inclusion criteria and processed in accordance with the preparation protocols. In order to ensure uniformity in the occlusal preparation process, a silicon putty index was created prior to the preparation process, and measurements were verified using a periodontal probe. Coltene/Whaledent AG (9450 Altstatten, Switzerland) was used to create duplicate silicon molds for the prepared tooth because it obtained impressions with less voids and bubbles (23).

The wax designs were milled using a 5-axis milling machine (Ceramill Motion 2 - Amann Girrbach AG, Austria) since it offers the best accuracy. This was demonstrated by Goujat et al.'s 2019 (15) study, which found that when it comes to the occlusal marginal gap and axial internal gap, a 5-axis milling machine performs better than a 3-axis milling machine.

As far as we are aware, this is the first study to look into the Vita Ambria's (pressable ZLS) fracture resistance. As a result, the current study's findings could be contrasted with those of previous investigations that tested CAD/CAM ZLS, including Vita Suprinity.

The null hypothesis is rejected since the findings showed that Vita Ambria has a much higher FR than the E-max Press. This might be explained by the addition of zirconia particles, which might impede the development of cracks and hence need greater load levels to fully fracture.

The present results are consistent with those of Elsaka and Elnaghy (5), who concluded that specimens of Vita Suprinity demonstrated significantly higher levels of FR compared to those of IPS e.max CAD. They attributed this difference in FR to the former's fine homogeneous crystalline structure versus the latter's needle-shaped crystals embedded in the glassy matrix, as well as the latter's high levels of fracture toughness recorded by ZLS as a result of the incorporation of zirconia particles, which reinforce the glassy matrix without causing clouding it via their dissolution (6). Additionally, ZLS crowns showed more FR than LDS crowns, as reported by Hamza & Sherif (7), who also explained their findings in terms of the differences in the microstructure of the two materials. According to a study by Ghajghouj and Taşar-Faruk (8), ZLS endocrowns (1784 N) have a much higher FR than LDS endocrowns (1196 N). According to a different study by Al-Akhali et al.(3), LDS exhibited higher fracture resistance than ZLS before to thermomechanical fatigue; however, tests done after thermomechanical loading revealed that LDS had poorer fracture resistance.

The manner each specimen failed (Burke's classification) may not accurately resemble the clinical conditions, but it offers a standardized method for comparing different groups. However, when applied in a clinical setting, types I, II, III, and IV represent fractures of the restoration without fractures of the underlying prepared tooth, which can be clinically treated by replacing the restoration, whereas type V includes fractures of the prepared tooth, which may be irreversible.

The results of this study revealed that the IPS e.max Press overlays have shown larger percentage of type V failure in comparison to the Vita Ambria overlays (type V is 76.9% for e-max versus 23.1% for Vita Ambria). This supports the fracture resistance results in the favor of the zirconia reinforced lithium silicate material. These results are in accordance to those obtained by Elsayed et. al (13) who also found greater percentage of type V failure in the restorations fabricated from lithium disilicate than those fabricated from zirconia reinforced lithium silicate and attributed this to the materials' composition.

Traditionally, it was claimed that to avoid restoration fracture failure, increased ceramic thicknesses accompanied with tooth structure reduction were advised (24). However, according to the recent biomimetic concepts it's important to preserve the tooth structure that remains when significant portions have been lost due to caries, attrition, or erosion (24). Nowadays, scientific research has proved that there is a well-established link between increased tooth structure loss and strength degradation (25).

Therefore, expanding preparation designs from inlays and partial coverage onlays to complete-coverage crown restorations at the expense of the remaining tooth structure, which is traditional restorative treatment concepts for posterior teeth, frequently sought to strengthen the tooth/restoration complex usually result in fracture failures of these restorations affecting both the restoration and the underlying tooth structure and are typically regarded as catastrophic (25). Furthermore, these wide whole coverage crown preparation designs compromise the health of the tooth (25). The current study has implemented the overlay preparation design and demonstrated acceptable fracture loads which may encourage the use of the overlay design in the clinical practice.

The current study examined a novel pressable dental ceramic material that has demonstrated higher fracture resistance than the IPS e.max Press, which is known to be the standard material when high precision—a pressable material's key benefit—is required. Therefore, further research should be done to support dentists in selecting the best treatment option given the various clinical circumstances. However, scientific investigation into the numerous partial coverage preparation techniques is always needed.

However, when fracture resistance is the parameter to be tested, in vitro studies are considered as a reliable testing method where an indication is derived about the mechanical characteristics of the material under clinical conditions. The limitations of this study are the inability to fully simulate the oral environmental conditions and the experimental techniques could have been the use of epoxy resin dies rather of natural human premolars. This is because, even with the obtained standardization, the processes could have led to some variation in the clinical response to fatigue.

CONCLUSIONS

Based on our results, it can be advocated that pressable ZLS restorations offer higher values of FR than restorations made of LDS.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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