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COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF DIFFERENT CAD/CAM FABRICATED ENDOCROWNS - IN VITRO STUDY

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ABSTRACT

Background: The aim of the study was to compare the fracture resistance of recent CAD/CAM restorative materials that recently used for the fabrication of endocrown restorations.

Methods: 30 endocrowns were fabricated on 3D printed resin dies and divided into three groups (n=10) according to the endocrown material. Group A: lithium disilicate Endocrowns (IPS E-max CAD), Group B: resin infiltrated ceramic (Vita Enamic), and group C: Nanohybrid composite (Brilliant Crios). All endocrowns were subjected to axial compressive strength using a universal testing machine, until failure, and the values were recorded. Fracture resistance values in Newton (N) and failure modes of the restorations were evaluated using an optical microscope. All collected data were tabulated and statistically analyzed. Numerical data were described as mean and standard deviation and compared using a Two-way ANOVA test. The level of significance was set at α $P \leq 0.05$.

Results: fracture resistance values of all tested materials were within the acceptable clinical range for all groups. The lithium disilicates endocrowns showed statistically significantly higher mean fracture resistance values than the polymer infiltrated and nanohybrid composite endocrowns. While the nanohybrid composite Endocrowns showed better mode of fracture than that of lithium disilicate.

Conclusions: Within the limitations of this study, Emax endocrowns showed better fracture resistance followed by Vita enamic endocrowns. While brilliant crios Endocrowns revealed a better mode of failure despite it's low fracture resistance values.

KEYWORDS: glass ceramics – hybrid composite – resin infiltrated ceramics

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INTRODUCTION

For restoration of teeth that were subjected to endo-treatment, the use of post and core approach with full coverage crown was the conventional line of treatment. The preparation of the tooth root canals and the reduction of post space lead to a decrease in the amount of remaining sound tooth structure and weakening of the tooth and also lead to uneven distribution of the stresses over the prepared tooth [(1)].

Restoring the posterior requires special characteristics in the restorative material used as posterior teeth are always subjected to occlusal forces during mastication. Many trials have been done to use new restorative approaches. Instead of the conventional method of full-coverage crown. In the last few years, the presence of the new adhesion concept in the dental field and the high bond strength that can be achieved using modern adhesive cements have changed the way of restoring endodontically treated teeth as adhesion provides reliable and sufficient retention of the restoration without the need of aggressive macro-retentive technique [(2)]. The significance of preserving the integrity of natural tooth structure, coupled with advancements in dental materials, has resulted in a growing preference for Endocrowns as a means of restoring teeth that have undergone endodontic treatment. This approach has gradually replaced the traditional method of employing posts, cores, and crowns in such cases. [(2)]. Glass-ceramics, such as lithium disilicate, or resin-infiltrated ceramics, have emerged as the preferred materials for constructing endocrowns due to their excellent aesthetics and dependable strength. Moreover, these materials exhibit high etchability, allowing for adhesive bonding to the natural tooth structure. By employing hydrofluoric acid etching gel, the silica content in these ceramics can be selectively removed, resulting in increased surface roughness that enhances the bonding capability with modern adhesive resin cements[(3)]. However, it is important to note that the brittleness of these ceramics has been identified as a primary disadvantage since it can potentially lead to catastrophic fractures. And also it can cause sever wear of the opposing teeth or restorations leading to a subsequent failure [(4)]. To avoid that, using a material with better stress distribution as nanohybrid composites has been suggested. For their better elasticity and favorable stress distribution properties. [(5)] To broaden the clinical applications of nanohybrid composites in endocrown restorations, it is crucial to gain a comprehensive understanding of the material's behavior and compare it with the lithium disilicate and polymer-infiltrated ceramics that are commonly used. This knowledge will enable dental professionals to make informed decisions about the most suitable material for each individual case, ultimately enhancing the success and longevity of endocrown restorations.

METHODS

Study design

Thirty endocrowns were fabricated on composite dies using a CAD/CAM system, and then divided into three main groups according to the material of endocrown restoration (n=10): Group A: lithium disilicate Endocrowns (IPS E-max CAD), Group B: Resin infiltrated ceramic (Vita Enamic) and group C: Nanohybrid composite (Brilliant Crios).

Endocrowns fabrication

Thirty 3D printed resin dies representing lower first molar teeth were fabricated with butt joint Endocrown preparation design. The pulpal cavity preparation depth was prepared to be 3mm and the axial wall thickness was prepared to be 2mm with a 10-degree divergence of the wall and occlusal reduction was made 3mm leaving 2mm wall height above the cementoenamel junction. For designing scanning and milling of restoration Cerec in Lab system (Sirona, Dentsply, Germany), inEosX5 Blue scanner, inLab MC X5 milling unit, and Cerec inLab (inLab Software 18.0) were used. All resin dies were scanned then restorations were designed.

A total of ten Endocrowns were milled from blocks of lithium disilicate material. (IPS e.max CAD blocks, Ivoclar Vivadent, Schaan, Liechtenstein)., Another 10 endocrowns, were milled out of polymer infiltrated ceramic blocks (Vita Enamic blocks, VITA Zahnfabrik, Germany) and the last 10 endocrown restorations were milled out of Nano-hybrid composite blocks (Brillient Crios, Coltene, Altstätten, Switzerland) (table 1). All restorations were applied to finishing and surface treatment according to the manufacturer's instructions. Dual-cured self-Adhesive resin cement (Breeze Automix, Pentron, United States) was used for the cementation of all restorations. Tuck curing was done for 5 seconds then excess cement was removed before the complete setting after that complete curing was done for more 30 seconds for each surface. The restorations were held in their position by applying constant finger pressure for 5 minutes.

Fracture resistance analysis

All restorations were subjected to load testing until fracture using a universal testing machine (Instron ElectroPuls E3000 & 5581, Instron Corporation, Norwood, MA, USA). Samples were fixed to the lower compartment of the testing machine with a screw. A compressive force was applied to restorations and was set at a crosshead speed of 0.5 mm/min until failure. A 5 mm diameter steel head semi-spherical indenter was placed in the central fossa of all restorations. In this study, the fracture was considered as the presence of cracks accompanied by a sudden drop in the load, specifically set at a 40% decrease in the loading force, as observed in the stress-strain curve diagram. The value of the fracture load, measured in Newtons (N), was recorded using specialized software, with the first drop in load marked as the corresponding point of failure. After that, all fractured specimens were examined under a stereomicroscope (Olympus SZ4045 TRPT, Osaka, Japan) using a magnification of ×30 to evaluate the mode of failure. The mode of failure was recorded and classified into: (restorable and non-restorable failures). A fracture is considered restorable if the level of fracture was above the physiologic level of bone (3mm apical to cementoenamel junction) [6] while if it's below the physiologic bone level the fracture is considered non-restorable.

Statistical analysis

To assess the distribution of the data, both the Kolmogorov-Smirnov and Shapiro-Wilk tests were employed. Statistical analysis and data management were conducted using SPSS software (Version 18, IBM Inc., New York, USA). Group comparisons were carried out using ANOVA, followed by post hoc Tukey tests. A significance level of $p \leq 0.05$ was considered statistically significant.

TABLE (1) Tested materials, compositions, and manufacturers

Material Name	Type	Composition	Manufacturer
Brilliant Crios	Nano Hybrid Composite	• Cross-linked methacrylate • (71 wt%) Silica SiO_2 <20 nm and Barium glass < 1 nm	Coltene, Altsẗatten,, Switzerland
Vita Enamic	Resin infiltrated ceramic	SiO_2 (60%) - Al_2O_3 (20%) - Na_2O (10%) - K_2O (4%) - B_2O_3 (0.5–2%) - KaO (<1) - ZrO_2 (<1)- IPS	VITA Zahnfabrik, Germany
Emax CAD	Lithium disilicate Glass ceramic	97% SiO_2-Na_2O -Al_2O_3- K_2O -P_2O_5-CaO- 3% TiO_2	Ivoclar Vivadent Schaan, Liechtensẗein

RESULTS

The results of the current study revealed that lithium disilicate ceramics recorded higher fracture mean values (3210.15a±972.11) than polymer infiltrated ceramics (2120.16b±943.60) while the nanohybrid composite restorations showed the lowest fracture resistance results (1866.15 c± 349.56). This was statistically significant ($p < 0.05$). (fig 1, table 2)

TABLE (2) Descriptive statistics of fracture resistance

Groups	n	Mean±SD	P value
Group A	10	3210.15a±972.11	0.007
Group B	10	2120.16b±943.60	
Group C	10	1866.15 c± 349.56	

Different letters indicated a statistically significant difference (P<0.005). SD=Standard deviation

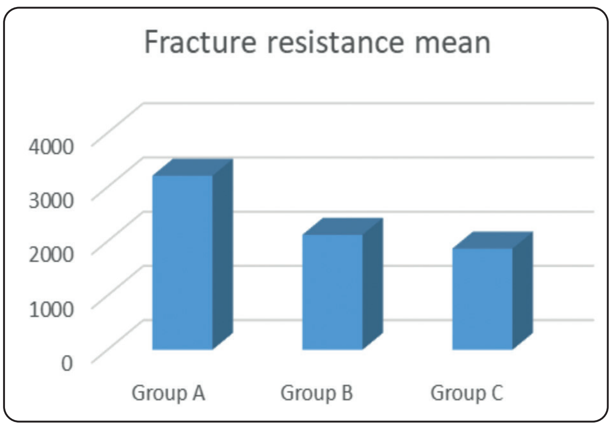

Fig. (1) Graph representing fracture resistance mean values of different groups

Frequent distribution scores (%) of the restorations' failure modes are represented in Table 3. The results of the failure mode showed that nanohybrid composites have favorable fracture modes while lithium disilicates showed the worst fracture modes. This was also statistically significant ($p < 0.05$).

TABLE (3) Percents of different failure modes for the tested materials

Variables		Failure mode		P value
		Restorable	Non- restorable	
Groups	Group A	20 %	80%	<0.0001
	Group B	40%	60%	
	Group C	70%	30 %	

DISCUSSION

Many research studies have agreed on the acceptable performance of endocrown restorations for restoring posterior endodontically treated teeth regarding esthetics and fracture strength(7). Lithium disilicate is the material of choice that is widely used for endocrown fabrication despite the disadvantages of this material that might affect the clinical performance of the restoration(8). In recent research, there has been a specific emphasis on examining the biomechanical properties of contemporary materials in order to achieve improved and more favorable outcomes. It is widely acknowledged that the effectiveness of any dental restoration is primarily determined by its ability to resist fractures and endure the forces exerted during mastication(9). Accordingly, this study investigated fracture resistance of different recent CAD/CAM materials that can be used for the fabrication of endocrowns. The results of the current study presented that; the type of the material considerably affected the fracture resistance of the restoration (10).

3D printed resin dies were used for standardization of the results to overcome variability in size and bonding quality to natural teeth that can be affected by the amount of available enamel and dentine in each tooth. These variations can greatly affect the results of fracture resistance tests (11).

The standardization of cavity preparation was done according to Hayes et al (12). who described the recommended molar teeth preparation to be restored with endocrowns with a pulp-chamber depth of

3 mm, authors added that endocrowns with deeper pulp chambers tend to have catastrophic fractures.

CAD/CAM system was used for the fabrication of the endocrown restorations in the current study for more accuracy and standardization of the occlusal thickness and cusps incline as it can affect the fracture resistance test results [(13)]. Choosing the butt joint preparation design was to decrease the complexity of the design and minimize the internal discrepancies [(14)].

In the current study, the force was applied in an axial direction along the long axis of the specimens to test the static loading and axial functional loading [(15)].

Regarding the fracture resistance, Emax group revealed statistically higher values of fracture resistance than the Vita Enamic and brilliant crios groups The fracture load values of Vita Enamic Endocrowns were found to be comparable to those of Emax CAD while the lowest values obtained by the Brilliant Crios group. This result might be due to the differences in microstructure of these materials which lead to differences in the mechanical properties. E max CAD material has high flexural strength (360 MPa) while the flexural strength of Vita Enamic (180-190 MPa) and of Brilliant Crios is (150-160 MPa). In addition to the needle-shaped crystalline structure of the Emax which increases the fracture resistance against loading as better counters the load [(16)].

The findings of this particular in-vitro study were consistent with other research studies [(17)], which also reported that lithium disilicate glass ceramics exhibited the highest fracture resistance [(18)].

A study conducted by Altieret al. [(17)] reported that lithium disilicate (IPS e.max CAD) posterior endocrowns exhibited higher fracture strength compared to resin nanocomposite materials such as Solidex and Grandia when subjected to axial load. Similarly, Naffah et al [(19)] proved that lithium disilicate and Enamic restorations had higher fracture resistance when they compared to Brilliant Crios and Cerasmart restorations.

In contrast, Emam and Aleem[(20)], reported different results in their study. They investigated the fracture resistance of occlusal veneers made from Brilliant Crios, Vita Enamic, and lithium disilicate after cyclic loading. The results were that Brilliant Crios had the highest mean fracture resistance, which was statistically significant compared to Vita Enamic and lithium disilicate. The explanation was that the resin polymer in the microstructure of the hybrid ceramics increases their resistance to the propagation of cracks compared to other ceramic materials.[(21)] On the other hand, another in-vitro study[(22)], proved that Vita Enamic material has higher fracture resistance than that of Emax CAD restorations.

Regarding the failure mode, There was a notable catastrophic fractures observed in IPS e.max CAD endocrowns.. The modulus of elasticity can be the main factor for this observation as It influences the vulnerability of the ceramic materials to fracture [(23)]. In areas recognized as critical, the presence of stress concentrations caused by the lack of flexibility in rigid materials like lithium disilicate can result in severe fractures in the restorations.[(24)], Conversely, materials that exhibit greater resilience and elastic modulus similar to natural teeth are capable of distributing stresses more evenly when subjected to a load. [(25)].

The study groups revealed that all instances of catastrophic failures occurred at loads significantly higher than the normal masticatory functional load. These findings were further supported by other independent studies. [(26)].

CONCLUSION

Within the limitations of this study, Emax endocrowns revealed better fracture resistance but a less favorable failure mode while brilliant crios Endocrowns revealed a better mode of failure than all other materials despite of its low fracture resistance.

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