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INFLUENCE OF DIFFERENT MARGINAL PREPARATION DESIGNS ON THE FRACTURE RESISTANCE OF VITA AMBRIA AND VITA SUPRINITY ENDOCROWNS (IN VITRO STUDY)

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ABSTRACT

Aim: This study evaluated the fracture resistance of endocrowns with two marginal preparation designs and manufactured with two all ceramic materials.

Methods: Twenty endodontically treated maxillary premolar teeth were prepared to receive endocrown restorations and divided into two equal main groups according to the preparation designs; endocrowns with butt joint design and endocrowns with ferrule design (n=10). The main groups were subdivided into two equal subgroups according to all ceramic material used; endocrowns manufactured from Vita Ambria and endocrowns manufactured from Vita Suprinity (n=5). The endocrown restorations were cemented to the prepared teeth using dual cured self-adhesive resin cement. The specimens were subjected to thermo-cycling. All specimens were subjected to a compressive force until fracture by using universal testing machine. The maximum compressive force was recorded for all the specimens, then the failure modes were examined using a digital microscope.

Results: Regarding the two materials effect, there were non-significant difference between Vita Ambria and Vita Suprinity on fracture resistance (P=0.66). Regarding the two marginal preparation designs effect, there were non-significant difference between butt joint and ferrule designs on fracture resistance (P=0.73). Regarding the failure mode, there was non-significant difference between all failure mode patterns in all groups except Vita Suprinity with butt joint design.

Conclusion: There was no significant difference between Vita Ambria and Vita Suprinity endocrowns, either using ferrule or butt joint design in this study.

KEY WORDS: Endodontically treated premolars; CAD/CAM; ferrule design; butt joint design.

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INTRODUCTION

Restoring endodontically treated teeth with extensive coronal destruction poses challenges due to reduced strength after pulp and dentin tissue removal**.** Poor retention often necessitates the use of endodontic posts and cores for crown retention. However, this system has drawbacks, including the risk of root fracture with rigid posts, and limitations in placement for curved, dilacerated, and calcified roots **(Atlas et al., 2019).**

Advances in adhesive dentistry have reduced the use of posts and cores. High-strength ceramic materials, like lithium disilicate reinforced materials, and improved adhesive systems facilitate the restoration of posterior teeth, including molars, without the need for cores or posts in the root **(Shi et al., 2022).**

Endocrowns, single monolithic restorations, bond to endodontically treated teeth using adhesive resin cement and operate on the 'monoblock' principle, functioning as a single unit **(AlDabeeb et al., 2023).** The monoblock nature enables superior resistance to stress loads compared to conventional restorations. Endocrowns are suitable for patients with limited interocclusal space. However, it remains unclear if endocrowns are suitable for restoring endodontically treated maxillary premolars due to reduced bonding surface area and unfavorable ratios between intra-coronal and extra-coronal extension **(Sedrez-Porto et al., 2016).**

Endocrown materials should be adhesive, with etchable glass ceramics, particularly lithium disilicate-based ceramics, emerging as promising monolithic choices (**AlDabeeb et al., 2023**). Zirconia-reinforced lithium silicate (ZLS), a recent development, is available as machinable CAD blocks (Vita Suprinity) and pressable pellets (Vita Ambria), released in 2019 (**Manziuc et al., 2023**).

Despite limited information **(Al Fodeh et al., 2023)**, the biomechanical impact of various endocrown designs and materials on maxillary premolars is not well-understood. **(Thomas et al., 2020)** comprehensive study suggested comparable performance of endocrown restorations on molar and premolar teeth**.** However, the bond durability of endocrowns on premolar teeth might be compromised due to their smaller bonding surface.

The gold standard for tooth restoration emphasizes minimally invasive preparation to preserve natural tooth structure. Endodontically treated teeth often require suitable coverage restorations to minimize the risk of fracture **(Krastl et al., 2021)**. Endo-crowns are gaining popularity due to their advantages in preserving dental tissue, reducing the need for additional retentive features, and lowering treatment time and cost.

Few researches have investigated the fracture resistance of various all-ceramic materials with different preparation designs for endocrown restorations in maxillary premolars that have undergone endodontic treatment **(Al Fodeh et al., 2023)(Haralur et al., 2020)(Ahmed et al., 2022) (Ghajghouj & Taşar-Faruk, 2019)(Naji et al., 2021)**. Hence, this study sought to assess the fracture resistance of endocrowns constructed from Vita Ambria and Vita Suprinity ceramics, utilizing two distinct preparation designs: butt joint and ferrule (finish line).

According to the null hypothesis, there would be no significant variation in fracture resistance between Vita Ambira and Vita Suprinity endocrowns, as well as between circumferential ferrule and butt-joint design preparations.

MATERIALS AND METHODS

Teeth Selection and storage

Twenty sound maxillary premolars, extracted for orthodontic purposes, were selected with inclusion criteria of being caries-free and having similar dimensions. Measurements were taken using a digital caliper (Hogetex, China) at the cemento-enamel junction (CEJ), accepting a deviation of +/- 0.5 mm. Any external debris was eliminated using an ultrasonic scaler, and the teeth were subsequently stored in distilled water **(Ahmed et al., 2022).**

Endodontic Treatment

The same operator performed standardized endodontic treatment on all teeth, using a carbide Round Burs (Dentsply Maillefer, Switzerland) for access cavity creation. An engine-driven rotary Nickel-Titanium (NiTi) device was used for canal enlargement, with a 0.4 mm diameter and a 2-degree taper for apical preparation using the crown-down method. Any excess gutta-percha within the pulp chamber was eliminated by utilizing a round bur equipped with a water-cooling system after completing root canal treatment on all teeth, extending up to the canal entry points.

Teeth Mounting

Teeth were affixed in epoxy resin (KEMAPOXY 150, CMB chemicals, Egypt) using a dental surveyor (Bredent BF2 dental surveyor, Senden, south Germany), ensuring each tooth was parallel to its long axis. In order to mimic the natural biologic width, the teeth were positioned 2 mm below the cemento-enamel junction (CEJ) **(Alamin et al., 2019)** (Figure 1a-1b).

Decapitation of the Teeth

Each sample was secured to a parallelometer machine (Nouvag USA Inc., USA.) (Figure 2-a). A diamond grinding wheel (Mani, Japan) mounted on a straight-angle handpiece was used to horizontally decoronate all teeth, preserving 3 mm of tooth structure above the CEJ **(Carvalho et al., 2016)** (Figure 2-b)

Preparation of the teeth with Butt Joint Design

The pulp chamber was designed with an 8-degree coronal divergence and a 4 mm depth in order to remove undercuts. A tapered diamond-coated bur with a rounded end (Mani, Japan) was used at a right angle to the pulpal floor (Figure 2-c). A flowable composite material was used to seal the pulp floor (Tetric N-Flow; Ivoclar Vivadent; Schaan, Liechtenstein). Using a periodontal probe and the butt margin as a reference point, the preparation depth was standardized so that all samples had a symmetrical pulp chamber floor at a depth of 4 mm from the butt margin to the floor composite **(Darwish et al., 2017).**

Preparation of the teeth with Ferrule Design

This design incorporates an intracoronal preparation similar to the butt joint design. Externally, the remaining vertical portion of the crown was prepared using a tapered diamond-coated bur with a rounded end, featuring an 8-degree coronal

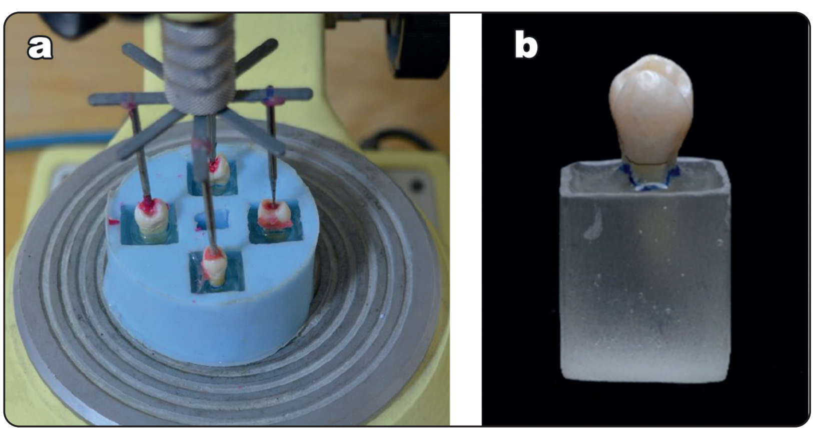

Fig. (1) Showing (a) teeth mounting using a dental surveyor; and (b) teeth mounting 2 mm apical to the CEJ.

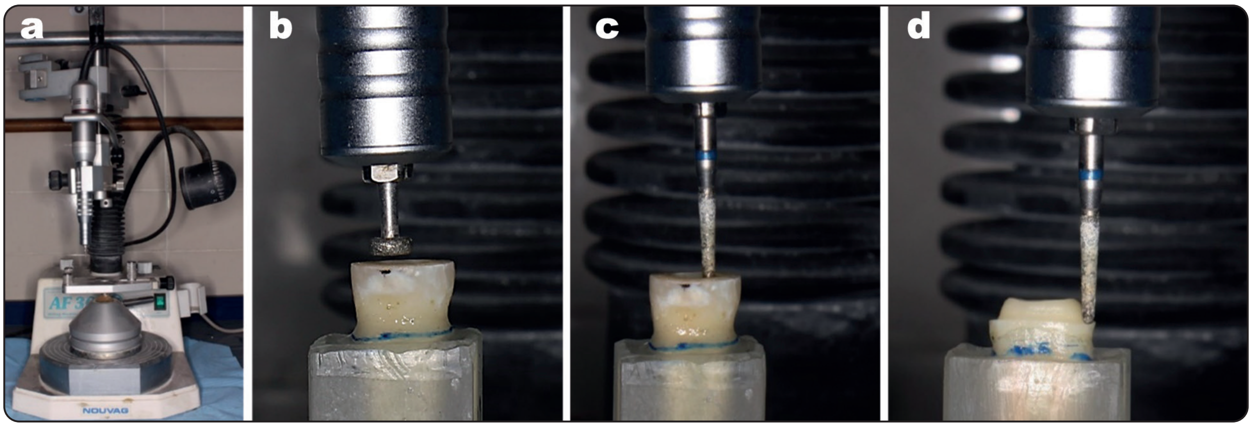

Fig. (2) Showing (a) AF 30 paralelometer machine NOUVAG; (b) specimen decoronation; and (c) axial preparation; and (d) preparing the teeth with chamfer finish line.

divergence. This established a circumferential deep chamfer finish line, measuring 1 mm in width. Positioned on healthy tooth structure, the finish line left a 2 mm ferrule with an 8-degree coronal convergence **(Darwish et al., 2017)** (Figure 2-d).

Fabrication of Endocrown Restoration

Prepared teeth were indirectly scanned with a desktop extraoral scanner (DS Dizar, Italy), and the inLab Software Dentsply Sirona 19.0 (Dentsply Sirona, USA) was used for restoration design. Due to inherent differences in tooth shape and morphology among selected maxillary premolars, achieving identical tooth morphologies posed a challenge. To overcome this inherent variation, specific design parameters were meticulously employed and consistently applied to all sample restorations, aiming to closely approximate the produced restorations to each other.

To ensure group standardization, a foundational scan was essential for the design of the restorations. This base scan, utilized for the biocopy feature in the CEREC software, was derived from the initial endocrown generated using the teeth library within the software. The tooth with the endocrown underwent rescanning to create a preoperative scan, which was then saved in the library. This saved scan served as a reference point for the design process of all other prepared samples in various groups (Figure 3).

Fig. (2) Showing (a) AF 30 paralelometer machine NOUVAG; (b) specimen decoronation; and (c) axial preparation; and (d) preparing the teeth with chamfer finish line.

Construction of Pressable Vita Ambria Endocrowns

Wax patterns for Vita Ambria samples were milled and pressed using the lost wax technique. STL files were imported into a dental CAM system to mill wax patterns from CAD wax blanks (Aidite CAD/CAM wax blank, China) using an inLab MC X5 milling machine (Dentsply Sirona, USA). The wax patterns were invested with Vita Ambria investment material (Vita Zahnfabrik, Bad Säckingen, Germany), The endocrowns were subjected to a burnout process in a furnace and subsequently heat-pressed using Vita Ambria ceramic ingots (Vita Zahnfabrik, Bad Säckingen, Germany). Rubber and diamond polishers (Meisinger, USA) were used to finish and polish pressed endocrowns. Ultrasonic cleaning with distilled water and a third step of heat tempering at 800°C were performed on Vita Ambria endocrowns. As advised by the manufacturer, glazing was done with Vita Akzent plus Glaze LT (Vita Zahnfabrik, Bad Säckingen, Germany) at 750°C (Figure 4a and 4b).

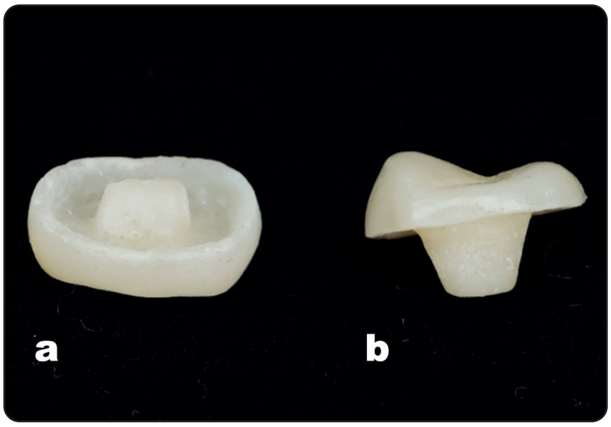

Fig. (4) Showing final Vita Ambria Endocrowns; (a) ferrule endocrown design; and (b) butt joint endocrown design.

Construction of Milled Vita Suprinity Endocrowns

Using an inLab MC X5 milling machine (Dentsply Sirona, USA), final restorations were milled using Vita Suprinity CAD CAM blocks (Vita Zahnfabrik, Bad Säckingen, Germany) based on sub-groups. After-milling, restorations were rinsed with water, dried, and coated with VITA firing paste on the outer surface. Placed on the firing tray, the restorations underwent crystallization using the Multimat NTX furnace (Dentsply Sirona, USA), following the manufacturer's specified firing parameters (Figure 5a and 5b) **(Elsayed et al., 2020).**

Cementation

Because the two materials used in this study are glass ceramics, they have the same protocol of bonding (Barallat et al., 2022). The restoration's inside surfaces were etched for 20 seconds using hydrofluoric acid (Porcelain Etchant 9.5% HF; BISCO, Inc., Schaumburg, IL, USA), followed by 40 seconds of washing, and drying. After applying the silane coupling agent (Porcelain Primer, Bisco, INC, USA), it was given a minute to dry.

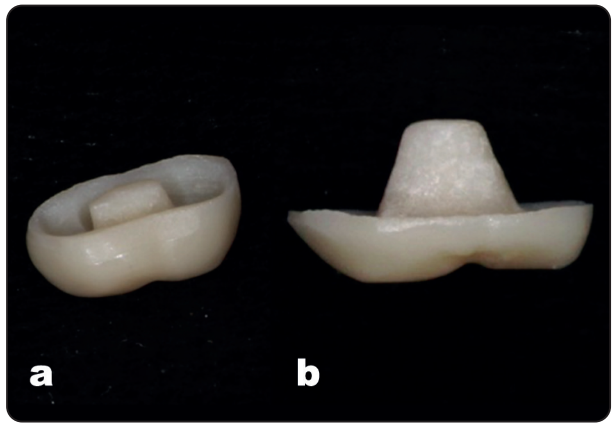

Fig. (5) Showing crystalized Vita Suprinity samples; (a) ferrule design; and (b) butt joint design.

The teeth's enamel edges were treated with 37% phosphoric acid for 20 seconds, followed by washing and air drying. After equally applying All Bond Universal (Bisco, INC., USA) on dentin or enamel, it was light-cured for 20 seconds. Fabricated endocrowns were bonded to corresponding samples using dual-cured resin cement (Breeze; Pentron, West Collin Ave, CA, U.S.A.) with a loading device. After removing any extra cement, each surface was light-cured for 20 seconds using adheive resin **(Alamin et al., 2019).**

Thermocycling Procedures

All samples were thermo-cycled utilizing a thermocycler machine (Robota automated thermal cycle; Bilge, Turkey) for 5000 cycles with a dwell time of 30 s, between 5°C and 55°C **(Elsayed et al., 2020).**

Fracture Resistance Test

The fracture test utilized a universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA). Each sample underwent a 5 KN load applied occlusally using a metallic rod with a diameter of 3.8 mm at a cross-head speed of 1 mm/min. To ensure uniform stress distribution and minimize local force peaks, a tin foil sheet was employed. The fracture load was measured in Newton (Figure 6).

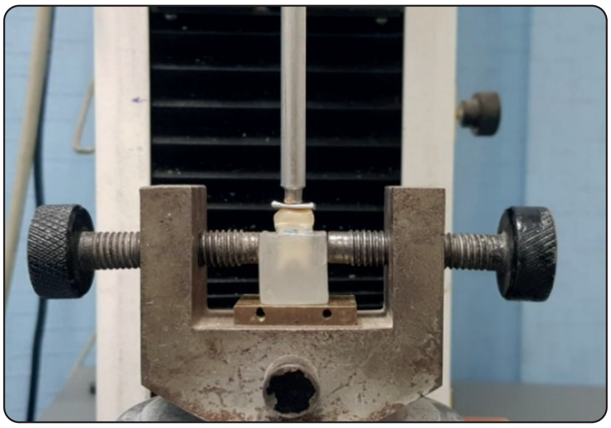

Fig. (6) Showing fracture resistance test of the ceramic endocrown.

Failure Mode

Following the fracture resistance test, a USB digital microscope (U500x Digital Microscope, Guangdong, China), was used to examine the fractured samples to identify failure modes. Patterns were categorized as Favorable (cracked or fractured restoration only) or Catastrophic (fractured restoration and tooth)**(Al-Zordk, 2019).**

Statistical Analysis

Statistical analysis utilized SPSS 20®, Graph Pad Prism®, and Microsoft Excel 2016. Data normality was assessed with the Shapiro-Wilk and Kolmogorov-Smirnov tests. Quantitative data were presented as mean and standard deviation, analyzed with One-Way ANOVA and student t-test for group comparisons. Two Way ANOVA was employed for evaluating the effect of different variables on fracture resistance. Qualitative data were presented as frequency and percentages and analyzed using the Chi-square test. Significance was set at $P<0.05$.

RESULTS

The obtained P-values (>0.05) indicated insignificance, suggesting normal distribution of parametric data in all groups. Group comparisons revealed no significant differences (Table 1). The comparison between butt joint and finish line ferrule designs, regardless of material, showed no significant difference, with a confidence interval (CI) of (-176.7, 126) (Table 2). Similarly, the comparison between Vita Ambria and Vita Suprinity materials, irrespective of design, showed no significant difference, with a CI of (-182.9, 119.1) (Table 2). Comparison between two different variable (material and design) effect on fracture resistance revealing both variables have insignificant effect of fracture resistance as regard material effect, and regard design effect as well as regarding the interaction between them (Table 3).

The mode of failure results revealed insignificant difference between all failure mode patterns in all groups except Vita Suprinity as Cracked restoration only (80%) was significantly the highest, fracture restoration and tooth (20%) was significantly the lowest, while fracture restoration was (0%), moreover, comparison between different materials revealed insignificant difference regarding all failure mode patterns (Table 4).

TABLE (1) Mean and standard deviation of both groups with different materials and comparison between them using One Way ANOVA test:

		M	SD	P value
Butt joint design (B)	**Vita Ambria (AB)**	1132 [a]	215.5	0.67 ns
	Vita Suprinity (SB)	1018 [a]	151.9	0.67 ns
Ferrule design (F)	**Vita Ambria (AF)**	1025 [a]	63.98	0.67 ns
	Vita Suprinity (SF)	1074 [a]	183.2	0.67 ns

TABLE (2) Comparison of design effect and material effect using independent test:

Design	Mean	SD	P value	Material	Mean	SD	P value
Butt joint design (B)	1075	185.7	0.72ns	Vita Ambria (A)	1078	160.1	0.66
Ferrule design (F)	1050	132	0.72ns	Vita Suprinity (S)	1046	161.4	0.66

TABLE (3) Two-way ANOVA analysis for the effect of different variables on mean fracture resistance:

	Sum of Squares (SS)	Degree of freedom (DF)	Mean square (MS)	F value	P value
Material effect	5086	1	5086	0.1898	0.6689
Design effect	3217	1	3217	0.1200	0.7335
Interaction Material effect X Design effect	33112	1	33112	1.236	0.2827

TABLE (4) Frequency and percentages of different failure modes in group B and F with different materials and comparison between them using Chi square test:

Failure mode pattern		Cracked restoration only		Fractured restoration		Fractured restoration and tooth		P value
		N	%	N	%	N	%	
Butt joint design (B)	Vita Ambria	2	40.0	1	20.0	2	40.0	0.51
	Vita Suprinity	4	80.0	0	0	1	20.0	0.01*
Ferrule design (F)	Vita Ambria	1	20.0	1	20.0	3	60.0	0.22
	Vita Suprinity	2	40.0	1	20.0	2	40.0	0.51
P value		0.07		0.31		0.22		

DISCUSSION

Recognizing the paramount importance of cavity design in maximizing restoration fracture resistance and preserving tooth structure **(Barallat et al., 2022)**, this in-vitro experiment aimed to assess the impact of various marginal preparation designs on the fracture resistance of Vita Ambria and Vita Suprinity endocrowns when restoring endodontically treated premolars.

The null hypothesis was accepted, as the study found no statistically significant difference between the two evaluated groups. Regarding preparation design, Vita Ambria and Vita Suprinity endocrowns with butt joint preparation demonstrated greater fracture resistance in prepared premolars, although not statistically significant, compared to circumferential ferrule prepared endocrowns. Additionally, no significant difference was observed in the fracture resistance of the same preparation design for the two tested materials, suggesting that endocrown fracture resistance is independent of material type.

Vita Ambria ingots and Vita Suprinity blocks, zirconia-reinforced lithium silicate monolithic ceramics, were chosen for endocrown fabrication. These materials are popular for endocrown creation, known for their single-substance composition and ability to fully anatomically restore missing tooth anatomy **(Borgia Botto et al., 2016).**

Premolars were chosen for testing endocrown fracture resistance due to their smaller adhesion surface and taller crown, which is more prone to failure. Premolars experience greater horizontally (non-axial) directed stresses compared to molars, influencing fracture resistance **(Alamin et al., 2019)**. Human premolars were selected for their biomechanical properties similar to clinical conditions, ensuring bonding and strength. Teeth were carefully chosen for size and shape uniformity, with a 10% maximum deviation from the mean **(El Ghoul et al., 2019).**

Epoxy resin, with an elastic modulus similar to human bone, was used to embed teeth roots 2 mm below the CEJ, mimicking natural bone levels **(El Ghoul et al., 2019).** A centralizing mechanism ensured vertical positioning in epoxy resin blocks for standardization. A parallelometer machine was employed to uniformly prepare teeth for all ceramic endocrowns **(Carvalho et al., 2016).**

Glass ceramics were acid etched before cementation with dual-cured resin cement to enhance mechanical strength, withstand occlusal forces, and promote adhesion to cavity walls, mimicking clinical scenarios **(Alamin, Sakr``ana and Al-Zordk, 2019)**.To prevent restoration rebound during cementation, a steady seating force of 1 kg parallel to the long axis was applied until the cement cured **(Ali et al., 2013).**

Specimens underwent 5000 thermocycles, equivalent to one year in clinical service **(Elsayed et al., 2020).** Furthermore, the testing of specimens was performed under axial (compressive) loading to replicate masticatory forces**(El Ghoul et al., 2019).**

Clinically, maximum posterior occlusal forces in the premolar region range from 222 to 445 N **(Zahran et al., 2008).** However, our investigation showed that all tested endocrown materials and preparation designs exhibited higher fracture resistance than expected in these clinical scenarios. This suggests that both the materials and design preparations effectively protect endodontically treated teeth from the maximum masticatory forces.

Regarding the preparation design, the findings of the present investigation showed that both the Vita Ambria and Vita Suprinity endocrowns with butt joint preparation had higher but not significant fracture resistance in the prepared premolars than in the circumferential ferrule prepared endocrown. This aligns with **(Shin et al., 2017)** study, which highlighted restricted dentin wall thickness with the inclusion of a ferrule, especially in the 2mm ferrule design. The circumferential ferrule preparation may involve excessive dentin removal, compromising the overall complex. Additionally, limitations in milling bur diameter can result in potential over-milling of intaglio features in areas with reduced dentin wall thickness **(Einhorn et al., 2019).**

This was supported by **(Biacchi & Basting, 2012)** findings. Who reported that because enamel is preferred to dentine bonding using the adhesive technique, to create a sufficient ferrule could lead to dental structure loss and harm bonding strength. In contrast, **(El-Refaay et al., 2020)** reported higher fracture resistance with ferrule preparation design compared to butt joint preparation. This difference could be attributed to the larger surface area available for adhesive bonding.

The current investigation found no statistically significant difference in the same preparation design for the two tested glass-ceramics. The negligible difference may stem from both materials being designed with lithium silicate as the primary crystalline phase within a vitreous matrix that was strengthened by crystals of zirconium dioxide. Zirconia particles are added for strength, acting as nucleating agents that interrupt cracks by dissolving in the glassy matrix **(Elsayed et al., 2020).**

However, the results concerning the mode of failure in this study, Vita Ambria exhibited 40%

catastrophic failure in butt joint and 60% in ferrule designs. In contrast, Vita Suprinity showed 20% catastrophic failure in butt joint and 40% in ferrule designs. This observation could be attributed to the higher modulus of elasticity exhibited by these materials compared to dentin (18.6 GPa). The Vita Ambria reported more catastrophic failures due to its high modulus of elasticity (100 GPa), while the Vita Suprinity possesses an estimated modulus of elasticity (70 GPa).

Vita Ambria and Vita Suprinity, with circumferential ferrule preparation, may be more prone to catastrophic failure, aligning with **(Einhorn et al., 2019)** findings on endocrown preparations. A 2mm ferrule displayed a tendency for catastrophic failure, while a 1mm ferrule showed reduced occurrences. The cervical thickness variation between butt joint and ferrule designs influences this phenomenon. Butt joint designs offer thicker cervical margins, promoting conservative treatment and enhancing restoration bonding and durability.

Limitations of the study

Since the simulation of masticatory forces was limited to a specific angle, translating the findings of this study directly into a clinical setting presents challenges, as commonly encountered in other in vitro investigations. Additionally, because this is an in vitro model, the absence of the periodontal ligament is evident and it is important to keep in mind that these findings do not provide information on how soft tissue would react at different heights of restoration margin.

CONCLUSION

Within the limitation of this study, those restorations in the maxillary premolar area can tolerate intraoral masticatory forces because all fracture resistance loads were greater than the maximal masticatory forces. There was no significant difference between Vita Ambria and Vita Suprinity endocrowns, either using ferrule or butt joint design in this study.

RECOMMENDATIONS

1. Further studies with a larger number of samples are recommended.
2. Future studies including different methods of oral environment simulation are proposed.
3. Clinical studies on the fracture resistance of different types of endocrowns for premolars are suggested.

Conflict of Interest

The authors declare no conflict of interest.

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Ethics

This study protocol was approved by the Ethical Committee, Faculty of Dentistry, Cairo University on 26\4\2022, approval number:(1422).

REFERENCES

- Ahmed, M. A. A., Kern, M., Mourshed, B., Wille, S., & Chaar, M. S. (2022). Fracture resistance of maxillary premolars restored with different endocrown designs and materials after artificial ageing. Journal of Prosthodontic Research, 66(1), 141–150.
- Al-Zordk, W. (2019). Effect of Preparation Design on Fracture Resistance and Failure Mode of Root Canal Treated Maxillary Premolars Restored with Onlay Restorations. Egyptian Dental Journal, 65(1-January (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)), 803–811.
- Al Fodeh, R. S., Al-Johi, O. S., Alibrahim, A. N., Al-Dwairi, Z. N., Husain, N. A.-H., & Özcan, M. (2023). Fracture strength of endocrown maxillary restorations using different preparation designs and materials. Journal of the Mechanical Behavior of Biomedical Materials, 148, 106184.
- Alamin, A. M., Sakrana, A. A., & Al-Zordk, W. A. E.-G. (2019). Impact of marginal preparation design on the fracture resistance of endo-crown all-ceramic. IOSR J Dent Med Sci, 18, 11–17.

- AlDabeeb, D. S., Alakeel, N. S., & Alkhalid, T. K. (2023). Endocrowns: Indications, Preparation Techniques, and Material Selection. Cureus, 15(12).
- Ali, A. M., Hamouda, I. M., Ghazy, M. H., & Abo-Madina, M. M. (2013). Immediate and delayed micro-tensile bond strength of different luting resin cements to different regional dentin. Journal of Biomedical Research, 27(2), 151.
- Atlas, A., Grandini, S., & Martignoni, M. (2019). Evidence-based treatment planning for the restoration of endodontically treated single teeth: importance of coronal seal, post vs no post, and indirect vs direct restoration. Quintessence Int, 50(10), 772–781.
- Barallat, L., Arregui, M., Fernandez-Villar, S., Paniagua, B., & Pascual-La Rocca, A. (2022). Fracture Resistance in Non-Vital Teeth: Absence of Interproximal Ferrule and Influence of Preparation Depth in CAD/CAM Endocrown Overlays—An In Vitro Study. Materials, 15(2), 436.
- Biacchi, G. R., & Basting, R. T. (2012). Comparison of fracture strength of endocrowns and glass fiber post-retained conventional crowns. Operative Dentistry, 37(2), 130–136. https://doi.org/10.2341/11-105-L
- Borgia Botto, E., Barón, R., & Borgia, J. L. (2016). Endocrown: A retrospective patient series study, in a 8 to 19-year period. Odontoestomatología, 18(28), 48–59.
- Carvalho, A. O., Bruzi, G., Anderson, R. E., Maia, H. P., Giannini, M., & Magne, P. (2016). Influence of adhesive core buildup designs on the resistance of endodontically treated molars restored with lithium disilicate CAD/CAM crowns. Operative Dentistry, 41(1), 76–82.
- Darwish, H. A., Morsi, T. S., & El Dimeery, A. G. (2017). Internal fit of lithium disilicate and resin nano-ceramic endocrowns with different preparation designs. Future Dental Journal, 3(2), 67–72.
- Einhorn, M., DuVall, N., Wajdowicz, M., Brewster, J., & Roberts, H. (2019). Preparation ferrule design effect on endocrown failure resistance. Journal of Prosthodontics, 28(1), e237–e242.
- El-Refaay, A. Y., Hassan, M. R., & Mohammed, R. M. (2020). Assessment of fracture resistance of endodontically treated premolars restored with endocrowns constructed of two different materials. Egy Dent J Research, 4, 533–542.
- El Ghoul, W., Özcan, M., Silwadi, M., & Salameh, Z. (2019). Fracture resistance and failure modes of endocrowns manufactured with different CAD/CAM materials under axial and lateral loading. Journal of Esthetic and Restorative Dentistry, 31(4), 378–387.
- Elsayed, M., Sherif, R., & El-khodary, N. (2020). Fracture resistance of Vita suprinity versus IPS e . max CAD vonlays restoring premolars (An in vitro study) Fracture resistance of Vita suprinity versus IPS e . max CAD vonlays restoring premolars (An in vitro study). October. https://doi.org/10.22271/oral.2020.v6.i3k.1029
- Ghajghouj, O., & Taşar-Faruk, S. (2019). Evaluation of fracture resistance and microleakage of endocrowns with different intracoronal depths and restorative materials luted with various resin cements. Materials, 12(16), 2528.
- Haralur, S. B., Alamrey, A. A., Alshehri, S. A., Alzahrani, D. S., & Alfarsi, M. (2020). Effect of different preparation designs and all ceramic materials on fracture strength of molar endocrowns. Journal of Applied Biomaterials & Functional Materials, 18, 2280800020947329.
- Krastl, G., Weiger, R., Filippi, A., Van Waes, H., Ebeleseder, K., Ree, M., Connert, T., Widbiller, M., Tjäderhane, L., & Dummer, P. M. H. (2021). Endodontic management of traumatized permanent teeth: a comprehensive review. International Endodontic Journal, 54(8), 1221–1245.
- Manziuc, M., Kui, A., Chisnoiu, A., Labuneț, A., Negucioiu, M., Ispas, A., & Buduru, S. (2023). Zirconia-Reinforced Lithium Silicate Ceramic in Digital Dentistry: A Comprehensive Literature Review of Our Current Understanding. Medicina, 59(12), 2135.
- Naji, A. M., Abo-Madina, M. M., & Hassouna, M. (2021). Fracture Resistance of Endocrowns Manufactured with Different Preparation Designs and Different CAD/CAM Materials.
- Sedrez-Porto, J. A., da Rosa, W. L. de O., da Silva, A. F., Münchow, E. A., & Pereira-Cenci, T. (2016). Endocrown restorations: A systematic review and meta-analysis. Journal of Dentistry, 52, 8–14.
- Shi, H. Y., Pang, R., Yang, J., Fan, D., Cai, H., Jiang, H. B., Han, J., Lee, E.-S., & Sun, Y. (2022). Overview of several typical ceramic materials for restorative dentistry. BioMed Research International, 2022.
- Shin, Y., Park, S., Park, J.-W., Kim, K.-M., Park, Y.-B., & Roh, B.-D. (2017). Evaluation of the marginal and internal discrepancies of CAD-CAM endocrowns with different cavity depths: An in vitro study. The Journal of Prosthetic Dentistry, 117(1), 109–115.
- Thomas, R. M., Kelly, A., Tagiyeva, N., & Kanagasingam, S. (2020). Comparing endocrown restorations on permanent molars and premolars: a systematic review and meta-analysis. British Dental Journal, 1–9.
- Zahran, M., El-Mowafy, O., Tam, L., Watson, P. A., & Finer, Y. (2008). Fracture strength and fatigue resistance of all-ceramic molar crowns manufactured with CAD/CAM technology. Journal of Prosthodontics, 17(5), 370–377.