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Fracture strength of endocrown maxillary restorations using different preparation designs and materials

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ABSTRACT

Purpose: This study investigated the impact of preparation design and material types on fracture strength in maxillary premolars endocrowns after thermodynamic aging.

Materials and methods: Eighty two-rooted maxillary premolar crowns underwent endodontic treatment ($N = 80$, $n = 10$). The teeth were categorized into ten groups (4-mm deep with no intracanal extension lithium disilicate glass ceramic & multilayer zirconia endocrowns (LE0 & ZE0); 4-mm deep with 4-mm intracanal extension in one canal (LE1 & ZE1); 4-mm deep with 2-mm intracanal extensions in both canals (LE2 & ZE2); flat overlays with no endocore (LO & ZO); glass fiber reinforced post & core and crown (LC & ZC)). After cementation, all specimens were subjected to 1500 thermocycles and 1,200,000 chewing cycles with an axial occlusal load of 49 N. A static loading test was performed at a non-axial 45° loading using a universal testing machine and failure modes (Type I: restoration debonding; Type II: restoration fracture; Type III: restoration/tooth complex fracture above bone level; Type IV: restoration/tooth complex fracture below bone level) were evaluated using a stereoscope. Data were ananalzed using 2-way ANOVA and Tukey's tests ($alpha = 0.05$).

Results: The endocrowns manufactured from multilayered zirconia and pressed lithium disilicate glass ceramic exhibited a fracture load ranging between 1334 ± 332 N and 756 ± 150 N, with ZC presenting the highest and LE2 the lowest values. The differences were not statistically significant ($p > 0.05$).

Conclusion: All endocrowns tested in this study performed similar considering the different designs and materials tested. The distribution of fracture modes did not differ significantly depending on the design of the restoration and the type of material used.

1. Introduction

Endodontic therapy can alter the tooth's biomechanical behavior, attributed to alterations in tissue composition, dentin micro- and macrostructure, and overall tooth structure. Factors such as trauma, cavities, endodontic access preparation, canal enlargement, use of particular chemicals, and post implantation frequently cause considerable tooth structure loss. Consequently, the remaining sound tooth structure is inadequate to maintain a casted replacement without additional support (Dietschi et al., 2007). Therefore, endodontically treated teeth are usually restored using a combination of post retained restoration and a crown (Govare and Contrepois, 2020). However, the adhesive dentistry's expanding popularity has shifted treatment decisions toward more conservative approaches. Ceramic inlays, onlays, overlays, and endocrowns have been introduced as alternative restorations for endodontically treated molars (El-Damanhoury et al., 2015).

In 1995, Pissis introduced a porcelain core/crown technology, presenting the monobloc technique as a substitute for the conventional metal post and core (Pissis, 1995). The technique further advanced the endocrown approach in 1999. As an adhesive crown, it was characterized as being applied for posterior endodontically treated teeth (Bindl and Mormann, 1999).

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Endocrowns are monoblock restorations that integrate the intra-radicular post, core, and crown (Sedrez-Porto et al., 2016). These restorations have proven to be a promising option for both post-retained molars and premolars (Govare and Contrepois, 2020). While extensive research has been conducted on endodontically treated molars, studies focusing on premolars are limited (Govare and Contrepois, 2020). Bindl et al. presented endocrown restorations for molar and premolar crown reconstructions (Bindl et al., 2006), emphasizing their potential as a therapeutic option for premolars. Endocrowns in maxillary endodontically treated premolars demonstrated superior fracture resistance compared to conventional post-core supported crowns on maxillary premolars (Bindl and Mormann, 1999; Chang et al., 2009; Bernhart et al., 2010; Gresnigt et al., 2016). Premolar endocrown failure is hypothesized to be related to a smaller adhesion surface compared to molars, along with a higher ratio of prepared tooth structure to total crown size (Bindl et al., 2006). Regarding fracture strength, endocrowns exhibited better performance than post and core systems, as well as inlays and onlays (Sedrez-Porto et al., 2016). The depth of the central cavity was not uniform and ranged from 1 to 4 mm. Similarly, the precise dimensions of the endo-core have not been definitively determined (Bindl et al., 2006; Chang et al., 2009). Recent research stated that the load-to-failure of restored endodontically treated maxillary single rooted premolars was increased in case resin composite compared to lithium disilicate glass-ceramic (Pedrollo Lise et al., 2017). The height discrepancy between Pulp chamber floor and crestal bone in the mechanical fatigue performance of endodontically-treated teeth restored with resin composite endocrowns was investigated and it was concluded that, the insertion level of the dental element to be rehabilitated with an endocrown interferes in the mechanical fatigue performance of the set. The discrepancy between the crestal bone height and the pulp chamber floor has a direct effect, in which the higher the pulp chamber floor in relation to the crestal bone, the greater the risk of mechanical failure of the restored dental element. The lower the pulp chamber floor in relation to the crestal bone, the greater the risk of irreparable failures (Ribeiro et al., 2023). Another recent study investigated the influence of remaining axial walls of tooth structure and restorative materials on fatigue resistance of endocrown restorations in premolars and concluded that, Zirconia endocrowns [ultra-translucent zirconia 5Y-PSZ [KATANA UTML] showed better fatigue failure load (FFL) than lithium disilicate endocrowns [IPS e.max-CAD]), regardless of the number of remaining axis walls. Lithium disilicate and 5Y-PSZ endocrowns showed FFL higher than the normal masticatory loads. (Demachkia et al., 2023), In an investigation of severely damaged endodontically treated premolars, it was found that aged endocrowns with endo-core lengths of 2-mm and 4-mm had marginal integrity and fatigue resistance comparable to classical crowns (Rocca et al., 2018). When the fracture strength of endocrowns and overlays in endodontically treated teeth manufactured with monolithic lithium disilicate and zirconia were compared, it was concluded that Lithium disilicate endocrowns exhibit higher fracture strength and are more reliable compared to the other types of restorations examined. Endocrowns had more catastrophic failures compared to overlays (Veselinova et al., 2023). Despite the existing limited knowledge, only few is known about the effect of various endocrown designs and materials utilized for maxillary premolars (especially two rooted canals) on the biomechanical behavior. Additionally, one recent systematic review stated that the performance of endocrown restorations applied on molar and premolar teeth performed similar (Thomas et al., 2020), atohough the bond durability of premolar endocrowns might be inferior considering the smaller bonding area.

Therefore, the purpose of this study was to assess the impact of various endocrown designs and materials on the load-to-failure and aging of endodontically treated maxillary premolars. The null hypothesis was that there would be no significant differences in fracture of endocrowns placed in endodontically treated maxillary premolars using various designs and materials.

2. Material and methods

This study obtained ethical approval from the deanship of research of the Jordan university of science and technology. This research was granted the number 43/146/2021.

The inclusion criteria were defined as follows: maxillary first premolars, extracted within a maximum of 3 months, due to orthodontic purposes, were selected. The sample size for each subgroup ($n = 6$) was estimated based on a previous study (Gresnigt et al., 2016), with alpha = 0.05, power = 80%, and a dropout rate of 20%, resulting in a sample size of ($n = 8$) (Arifin and Zahiruddin, 2017) using the sample size calculator (Version 2.0) (Mean difference = 177, standard deviation = 106). In this investigation, a total of 80 intact, double-rooted maxillary premolars with nearly identical mesiodistal/buccolingual dimensions and root lengths were collected and randomly assigned to the ten test groups ($N = 80$, $n = 10$). For standardization of the sample, a digital radiograph (myray, CEFLA SC dental group, Italy) in mesio-disatal direction was taken of each tooth to confirm the presence of two canals in bucco-lingual view and absence of irregularities in the pulp chamber and root canals. In case of a different number of canal or irregularities in the pulp chamber the teeth were excluded from the study. To ensure uniformity in sample size, the crowns of teeth were measured in the mesio-distal (MD) and bucco-lingual (BL) dimensions using a digital caliper with a 0.01 mm accuracy. Teeth were ultrasonically cleaned before being kept in a 1% chloramine-T solution at room temperature.

The access cavity was prepared using a small round diamond bur (Punta Diamantata, DIAMIR, ITALY). The working length was 1 mm short of the apex by inserting a size 10 stainless-steel K-file (Rogin Dental, Shenzhen, China) until it was visible from the apex and then pulled back 1 mm. The root canals were prepared using a crown-down technique with a rotatory nickel-titanium system (Rogin Dental, Shenzhen, China) until reaching the apical size of an F1 file (Rogin Dental, Shenzhen, China). Between each file, an identical volume of 5 ml of 1% sodium hypochlorite (NaOCl) was used for 10 s. This protocol was followed for each tooth during the biomechanical preparation. Therafter, canals were dried using absorbent paper points (Sure-endo, Korea). The obturation process was carried out using the lateral condensation technique with F1 size gutta-percha (GP) and a root canal sealer (Meta Adseal Canal Sealer, Meta Biomed, Korea), adhering to the manufacturers' instructions, ensuring a standardized filling and obturation procedure.

Polyvinyl siloxane (addition silicone) duplicate material (Elite Double 32 fast, Zhermack, Rovigo, Italy) was used to cover all roots. The roots were encapsulated in epoxy resin within 33 mm PVC cylinders. All crowns were removed using a double-sided diamond disc (Henan Baistra Industries Corp. China) in a handpiece attached to a dental milling machine (Dentaurum Paramil 3/Germany) with water cooling. This study utilized five restoration designs (Fig. 1). The teeth were divided into ten groups (five with multilayer zirconia and the remaining with pressed lithium disilicate) and classified as follows: Endocrowns made of lithium disilicate glass ceramic or multilayer zirconia, and a 4 mm deep (LE0 & ZE0). Endocrowns made of lithium disilicate glass ceramic or multilayer zirconia, 4 mm deep with 4-mm intracanal extension in one canal (LE1 & ZE1). Endocrowns made of lithium disilicate glass ceramic or multilayer zirconia are 4 mm deep with 2-mm intracanal extensions in both canals (LE2 & ZE2). Negative control: Flat overlays made of lithium disilicate glass ceramic or multilayer zirconia (LO & ZO) (Rocca et al., 2018). Positive control: Glass fiber post & core and crown made of lithium disilicate glass ceramic crowns or multilayer zirconia (LC & ZC).

The axial walls of all specimens were prepared with an internal taper of 8–10° using a tapered diamond-coated stainless-steel bur with a rounded edge (Arum dental burs, China) held perpendicular to the pulpal floor. All internal line angles were rounded and flattened. Endocrowns were shaped using an 8 to10-degree tapered diamond-coated stainless-steel bur with a rounded end. The dimensions of the cavities were 2.75 ± 0.25 mm mesio-distally and 5.00 ± 0.25 mm

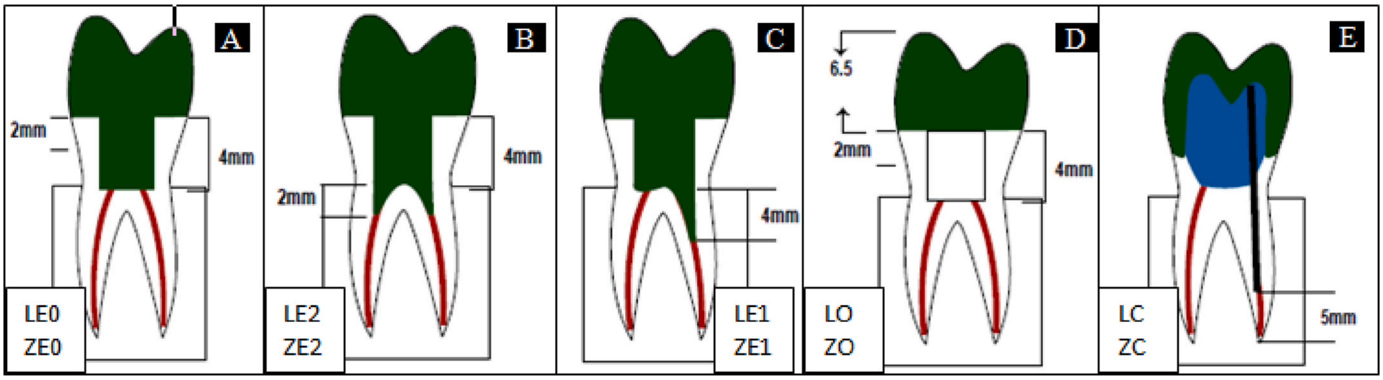

Fig. 1. A schematic illustration of designs. (A) 4-mm deep endocrown without intracanal extension. (B) 4-mm deep endocrown with two 2-mm intracanal extensions. (C) 4-mm deep endocrown with one 4-mm intracanal extension (D) Flat overlay (E) Fiber post & core and crown system.

bucco-palatally with at least 1.30 mm wide cavity margins. With Gattes Glidden drills, 5 mm of gutta percha was removed from the palatal canal for glass fiber post processing. The RelyX Fiber Post size 1 drill (3M ESPE, MN, USA) was used to prepare the post space. A 2 mm circumferential ferrule with a 1 mm depth was estabilished using a chamfer diamond bur (ISO-131) (DFS-Diamon, Lindenstrasse, Germany), prior to sealing of the fiber post with self-adhesive resin cement (RelyX U200 Automix, 3M ESPE, MN, USA) for 40 s, using a 1200 mW/Cm2 LED curing light (COXO DB-686 Latte LED Curing Light, Foshman COXO Medical Instrument Co. Ltd., Foshman, China). Therefore, an automix tip was utilized to get a homogenous mixing of resin cement and a lentulo paste carrier instrument was used to insert the cement into the canal. A standardized acetate index (Zhangzhou Huaer Electro Technology CO. Ltd. China) was placed over the prepared premolar dies and filled with bulk fill composite (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent AG, Shaan, Liechtenstein) to produce a standardized core form. All zirconia specimens were produced using computer-assisted design and manufacturing (CAD-CAM) technologies. In order to standardize the occlusal surface of all teeth's endocrowns, crowns, and overlays, all specimens were created using Ceramill Mindforms by Amann Girrbach (AG). Restorations made from zirconia blanks were sintered and polished (Ceramill Zolid Fx multilayer, Amann Girrbach AG, Herrschaftswiesen 1, Austria) according to the manufacturer's instructions.

Airborne-particle abrasion was applied with 50 μm aluminum oxide particles at a pressure of 2.5 bar for 20 s at distance of 10 mm to the inner surfaces of all zirconia endocrowns, crowns and overlays, and the internal surfaces were cleaned with alcohol and dried with oil-free air. After cleaning the inner surface, a thin layer of zirconia primer (Z-PRIME Plus, BISCO Inc. Schaumburg, USA) which contains 10-MDP was applied to the zirconia and air dry for 3–5 s. Etching of the tooth structure was performed according to manufacturer instructions (optional etching increase bonding capacity) using Scotchbond Etchant (3M ESPE, USA) which applied to tooth structure for 15 s then rinsed with water for 15 s also. Gentle dry with water free and oil free air. A disposable applicator was used to apply the Single Bond Universal Adhesive (3M ESPE, Germany) to the entire tooth structure, and it was rubbed in for 20 s. A gentle stream of air was applied over the adhesive agent for about 5 s until the solvent had evaporated completely. The adhesive agent was not cured until the dual cure resin cement ((RelyX Ultimate, A2 shade, 3M ESPE, Seefeld, Germany) was applied to the entire surface of cavity walls, floor and the surface of restoration to be cemented, then a constant load of 1 kg was applied over the restoration for 5 min to apply the same amount of force during cementation) to achieve the complete seating.

The cement was photo-polymerized for 90 s from all directions using a 1200 mW/Cm2 LED curing lamp. The lost wax specimens used lithium disilicate glass ceramic ingots (IPS e.max Press HT A2, Ivoclar Vivadent, Schaan, Liechtenstein). The accuracy of light curing was standardized for all samples using a spectroradiometer (Aphrodite LED radiometer CM-2500, Motion Medical Supplies & Equipment Corporation, Taiwan). The radicular section of the prepared teeth was used to generate a wax pattern for the endocrowns, and the coronal part of the endocrowns was used to modify a premade wax pattern. Spruing, investing, preheating, pressing, divesting, and polishing were done following the manufacturer's instructions. All specimens underwent surface treatment according to the manufacturer's guidelines. The inner surfaces of all lithium disilicate glass ceramic restorations were etched with 9.5% hydrofluoric acid HF (BISCO PORCELAIN ETCHANT, Schaumburg, USA) for 60 s, rinsed and dried. Etched surfaces were cleaned in an ultrasonic bath for 2 min to eliminate all residual acid and dissolved debris. A layer of silane agent (BISCO BIS-SILANE™, 2-Part Porcelain Primer, Schaumburg, USA) was applied over the inner surfaces for 30 s and then air-dried. Optional etching of the tooth structure was performed using 37% phosphoric acid (Scotchbond Etchant, 3M ESPE, USA) which applied to tooth structure for 15 s then rinsed with water for 15 s also. Gentle dry with water free and oil free air. A disposable applicator was used to apply bonding agent (Single Bond Universal Adhesive, 3M ESPE, Germany) to the entire prepared tooth structure, and it was rubbed in for 20 s. A gentle stream of air was applied over the adhesive agent for about 5 s until the solvent had evaporated completely. Dual cure resin cement ((RelyX Ultimate, A2 shade, 3M ESPE, Seefeld, Germany) was applied to the entire surface of cavity walls, floor and the surface of restoration to be cemented, then a constant load (1 kg) was applied over the restoration for 5 min to achieve the complete seating. The excess cement was removed using a sponge pellet before polymerization while a restoration was placed under constant load. Cement was light cured from all directions for 90 s using an LED curing light with a light power of ≥1200 mW/Cm^2 (COXO DB-686 Latte LED Curing Light, Foshman COXO Medical Instrument Co. Ltd., Foshman, China). Following cementation, all specimens were subjected to a total of 1500 thermo-cycles (5°C–55°C to 5°C with a 2-min dwell time) followed by 1,200,000 chewing cycles with a load of 49 N axial occlusal load applied via a stainless-steel ball on the buccal cusp at a frequency of 1.7 Hz. Each attached tooth was positioned at a 45-degree angle between the tooth's long axis and the loading jig in the universal testing machine. Force was applied via a corrosion-free steel intender with a diameter of 2.5 mm, which represented the antagonist teeth. At a crosshead speed of 0.5 mm/min, the load was applied to the inclination of the palatal cusp. The fracture force was measured in Newton. To determine failure mode, each specimen was examined using a stereoscope at 3.5x magnification. Statistical analyses were carried out to assess the significance of differences among the materials and designs studied. After homogenity testing (Table 1), 2-way analysis of variance (ANOVA) was employed followed by Tukey's post-hoc test. to identify significant variations. In addition, the Chi-square and Fisher Exact tests were employed to examine the distribution of failure mode among the tested groups. The significance level was

Table 1
Mean, standard deviation, minimum and maximum fracture load values of overall tested groups in Newton.

Group	Preparation design	N	Mean (N)	Std. Deviation (N)	Minimum (N)	Maximum (N)
LE0	4-mm deep, no intracanal extension	8	856.5	185.34	524	1132
LE1	4-mm deep, with 4-mm intracanal extension in 1 canal	8	843.5	273.9	608	1356
LE2	4-mm deep, with 2-mm intracanal extension in 2 canals	8	756	150.31	556	912
ZE0	4-mm deep, no intracanal extension	8	1087.5	407.42	428	1788
ZE1	4-mm deep, with 4-mm intracanal extension in 1 canal	8	888.5	239.23	420	1228
ZE2	4-mm deep, with 2-mm intracanal extension in 2 canals	8	870	187.13	604	1188
LO	Flat overlay with no endocore	8	938.5	382.01	460	1580
LC	Glass fiber reinforced post, core and crown	8	1074	260.38	648	1448
ZO	Flat overlay with no endocore	8	862.5	282.81	452	1200
ZC	Glass fiber reinforced post, core and crown	8	1333.75	332.93	880	1840
Total		80	951.08	310.6	420	1840

set at 0.05.

3. Results

The highest mean fracture load was recorded in ZC (1333.75 ± 332.93), followed by ZE0 (1087.50 ± 407.42), LC (1074 ± 260.38), LO (938.5 ± 382.01), ZE1 (888.5 ± 239.23), ZE2 (870 ± 187.13), ZO (862.5 ± 282.81), LE0 (856.5 ± 185.34), LE1 (843.5 ± 273.9), with the lowest mean fracture load in LE2 (756 ± 150.31) (Table 1). The ANOVA test revealed a statistically significant difference in fracture strength among the groups.

The analysis identified a statistically significant difference between the ZC group and the following groups: LE0, LE1, LE2, ZE2, and ZO (Tukey's test). No significant difference between groups with the same design and different materials (Table 2).

In terms of failure modes (Table 3), glass fiber posts and multilayer zirconia crowns exhibited the greatest percentage of catastrophic fracture (87%), followed by ZE1 (75%), ZE2 and LE1 (62.5%), LE2 (50%), ZE0 (37.5%), and lastly LC, LO, and multilayer ZO crowns (25%). ZO (25%) showed the highest debonding rates, followed by LE1 and LE2 (12.5%). Digital images are presented in Fig. 2 for each failure mode. The Chi-square and Fisher Exact (Table 4) tests demonstrated that the distribution of failure mode was not affected by the material or design of the restoration ($P > 0.05$).

4. Discussion

Based on the results of this study the null hypotheses was accepted in that different endocrown preparation designs and material types did not significantly influence the biomechanical behavior of endodontically treated teeth. Endocrowns serve as an alternative to post and core systems without compromising remaining tooth structure.

Among the restorative materials, endocrowns manufactured using lithium disilicate glass ceramic have been recognized as highly effective (Biacchi and Basting, 2012; Gresnigt et al., 2016). Therefore, in this research, endocrown restorations were compared to fiber post and crowns, flat overlay restorations, preparation designs (4 mm endo-core with no intracanal extension, 4 mm endo-core with 2 mm intracanal extensions in both canals, and 4 mm endo-core with 4 mm intracanal extension in palatal canal) and two different materials, namely lithium disilicate and zirconia. Specimens were subjected to chewing simulator to simulate in-vivo masticatory circumstances, with all specimens undergoing 1500 thermo-cycles (5°-50°C to 5°C with a dwell time of 2 min) and 1,200,000 chewing cycles (about 5 years of clinical function in premolar area) with a cyclic load of 49 N (Krejci et al., 1988; Wiskott et al., 1995; Kumagai et al., 1999; Rocca et al., 2016). None of the

Table 3
Failure mode distribution within groups.

Crosstab			Failure Mode Type				Total
			I	II	III	IV	
Material	LE0	Count	0	0	4	4	8
		% within Material	0.0%	0.0%	50.0%	50.0%	100.0%
	LE1	Count	1	0	2	5	8
		% within Material	12.5%	0.0%	25.0%	62.5%	100.0%
	LE2	Count	1	0	3	4	8
		% within Material	12.5%	0.0%	37.5%	50.0%	100.0%
	ZE0	Count	0	0	5	3	8
		% within Material	0.0%	0.0%	62.5%	37.5%	100.0%
	ZE1	Count	0	0	2	6	8
		% within Material	0.0%	0.0%	25.0%	75.0%	100.0%
	ZE2	Count	0	0	3	5	8
		% within Material	0.0%	0.0%	37.5%	62.5%	100.0%
	LO	Count	0	0	6	2	8
		% within Material	0.0%	0.0%	75.0%	25.0%	100.0%
	LC	Count	0	2	4	2	8
		% within Material	0.0%	25.0%	50.0%	25.0%	100.0%
	ZO	Count	2	0	4	2	8
		% within Material	25.0%	0.0%	50.0%	25.0%	100.0%
	ZC	Count	0	0	1	7	8
		% within Material	0.0%	0.0%	12.5%	87.5%	100.0%
Total		Count	4	4	34	38	80
		% within Material	5.0%	5.0%	42.5%	47.5%	100.0%

Table 2
Cross comparisons between groups of the same design and different materials.

Fracture Load		Levene's Test for Equality of Variances		Tukey's test			
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference
LE0/ZE0	Equal variances assumed	2.988	.106	−1.460	14	.166	−231.000
LE1/ZE1	Equal variances assumed	.277	.607	−.350	14	.732	−45.000
LE2/ZE2	Equal variances assumed	.079	.783	−1.343	14	.201	−114.000
LO/ZO	Equal variances assumed	.180	.678	.452	14	.658	76.000
LC/ZC	Equal variances assumed	1.199	.292	−1.738	14	.104	−259.750

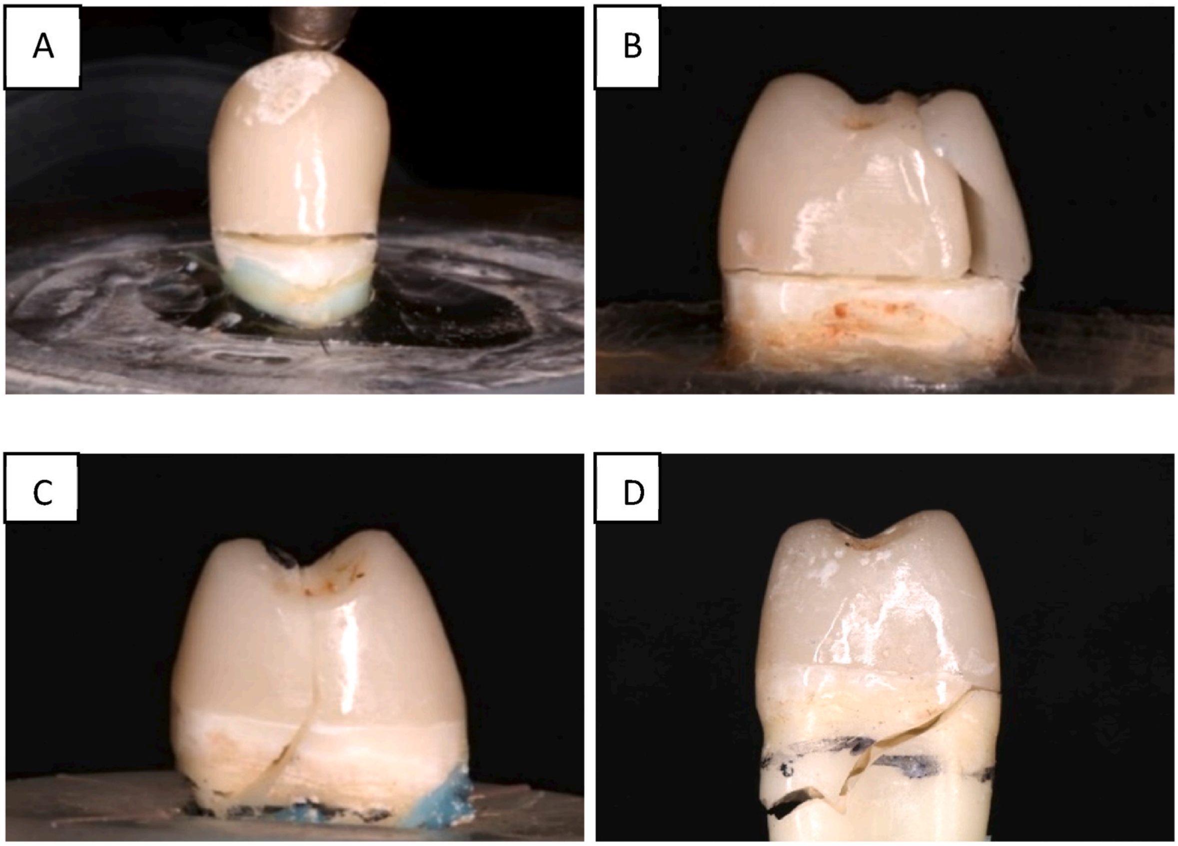

Fig. 2. Failure mode type. (A) complete or partial debonding of the restoration without fracture (Type I). (B) fracture of the restoration without fracture of the tooth (Type II). (C) fracture of the restoration/tooth complex above the height of bone level simulation (Type III). (D) fracture of the restoration/tooth complex below the height of bone level simulation (Type IV).

Table 4
Statistical analysis of all tested designs and materials.

Specimens of different designs and materials		P-value
Case 48 & Control 32 (lithium disilicate and zirconia)	4.049	.218
All tested groups (lithium disilicate and zirconia)	29.277	.133
Lithium disilicate glass ceramic case & control	6.604	.045
Lithium disilicate glass ceramic all tested groups	11.606	.334
Zirconia case & control	2.946	.233
Zirconia all tested groups	11.238	.103
Lithium disilicate glass ceramic restorations & multilayer zirconia restorations	3.112	.362

specimens failed throughout the 1,200,000 chewing cycles, indicating that the restorations can survive the repeated occlusal forces encountered by teeth (Kern et al., 1999). The typical premolar chewing force ranges from 222 to 445 N (average 322.5 N), while the peak biting force during clenching falls between 520 and 800 N (average 660 N) (Widmalm and Ericsson, 1982; Hidaka et al., 1999). The present study revealed no significant differences in the mean fracture strength of lithium disilicate glass ceramic endocrowns across the tested groups ($p > 0.05$). As a consequence, LE0, LE1, and LE2 performed similar, with an average fracture strength of 818.67 N. The absence of ferrule explains why our mean fracture resistance is lower than these observed in a former study (Forberger and Göhring, 2008). Our simulation intentionally omitted a ferrule, representing a worst-case scenario and potentially magnifying the influence of restoration design and materials (Juloski et al., 2014; Zicari et al., 2012). Studies have shown, that the presence of a ferrule improved the fracture resistance of endodontically treated premolars with endocrowns, glass fiber post-and core, and all ceramic crowns (Abdel-Aziz and Abo-Elmagd, 2015). This enhancement may be attributed to the preservation of tooth enamel at the preparation boundaries, contributing to adhesive retention and potentially impacting premolar fracture resistance (Chang et al., 2009; Lin et al., 2011). Likewise, endocrowns made of multilayer zirconia also exhibited no statistically significant differences with mean fracture strength values ranging from 870.00 to 1087.50 N. Fracture strength of endocrowns made of multilayered zirconia were similar, independent of endocrown length. In multilayer zirconia endocrowns, 948.67 N was the average tensile strength. No earlier research on multilayer zirconia for endocrown restorations are available. As the two materials have somewhat different mechanical properties, the mean fracture resistance of multilayer zirconia endocrowns was slightly higher than that of lithium disilicate. Endocrown depth did not affect the 45-degree load-to-failure of restored premolars, aligning with the findings of Lise et al. (Pedrollo Lise et al., 2017). Unintentional root perforation is reduced, and sound tooth tissue is not removed, preventing damages of the tooth-root complex (Pedrollo Lise et al., 2017). The endo-core length had no influence on fatigue resistance, according to one study (Rocca et al., 2018). The marginal integrity and fatigue resistance of fatigued endocrowns with 2-mm and 4-mm long endo-cores were comparable to conventional crowns. Two studies found similar results to our studies on solely endocrown repairs (Pedrollo Lise et al., 2017; Rocca et al., 2018). One other study reported that even with 4.5 mm occlusal reduction, 2 mm radicular extension of endocrowns improved fracture resistance (Haralur et al., 2020). With regard to premolar endocrowns, there was no evidence comparing lithium disilicate glass-ceramic with multilayer zirconia materials. One in-vitro study found larger resistance to failure with 2.5 mm deep endocrowns when using composite material for fabrication (Pedrollo Lise et al., 2017). On average, zirconia failures are twice as likely as lithium disilicate glass ceramics to cause catastrophic failures due to the higher elastic modulus (200 GPa) of zirconia comparing to that of lithium disilicate glass ceramic (95 GPa). The fracture resistance of endodontically treated premolars with lithium disilicate glass ceramic crowns was about 1074 N. Load-to-failure values for recovered teeth have previously ranged from 200 to 900 N (Cormier et al., 2001; Akkayan and Gülmez, 2002). According to one study lithium disilicate endocrowns and crowns were identical (Forberger and Göhring, 2008). There was no significant difference between endodontically treated premolars with endocrowns and conventional crowns (Lin et al., 2011; Lin et al., 2013; Pedrollo Lise et al., 2017; Rocca et al., 2018). As for flat overlays, lithium discilicate glass ceramic had a higher mean fracture resistance than zirconia. The debonding failure mechanism in zirconia overlays is hypothesized to occur because lithium disilicate has a stronger link with the tooth substrate. This is attributed to superior mechanical capabilities of multilayer zircônia over lithium disilicate glass ceramics (1333.75 N). Fiber post and zirconia crowns (7 specimens out of 8) exhibited the most unfavorable fracture mode, characterized by a higher root fracture, despite the failure mode distribution being minor across examined material groups. The high elastic modulus of zirconia prevents it from being flexible, concentrating stress in the rweakest area of the root (Habibzadeh et al., 2017). One study used 3D finite element analysis to construct an equivalent von Mises stress concentration at the interface of materials with varying modulus of elasticity (Zarone et al., 2006). A stiffer material with a higher modulus of elasticity may affect a comparable von Mises stress distribution.

In terms of failure distribution, although no significant differences were observed in fracture patterns between restorations using lithium disilicate and multilayer zirconia, it is important for clinicians to consider the distribution of fractures. Notably, 17 out of 40 catastrophic fractures occurred in the former restorations, while 23 out of 40 were observed in the latter group. Given these findings, it is advisable for clinicians to carefully assess the clinical context and patient-specific factors when choosing between endocrown restorations and post-and-core systems. Individual patient needs and risk factors should guide treatment decisions to ensure the most suitable and durable restoration is selected.

One limitation of the study is the use of maxillary premolar. However, in a systematic review and meta-analysis no significant difference in the rate of endocrown failures between molars and premolars were found. The available evidence suggests that endocrowns on both premolars and molars exhibit similar high rates of longevity, potentially making premolars suitable candidates for endocrown restorations (Thomas et al., 2020). One other limitation is the small indenter size and low cyclic load. However, the cyclic load of 49 N was used in many studies (Pedrollo Lise et al., 2017 used 50 N cyclic loading, G.T. Rocca et al., 2016) and made the results of the current study comparable. Furthermore, based on the form and morphology of the specimen, the majority of investigators preferred ball-shaped tips with diameters ranging from 2.5 to 6 mm. Facture load testing, being a destructive method, can be influenced by various factors, including tooth anatomy, age, and structure. Nevertheless, clinical studies should consider the preclinical findings prior to setting randomized clinical trials.

5. Conclusions

From this study, the following could be concluded:

1 No significant difference was found between various designs of endocrowns manufactured either using multilayer zirconia or pressed lithium disilicate glass ceramic.
2 Multilayer zirconia crowns with fiber posts outperformed their lithium disciliate counterparts in terms of fracture resistance.
3 The distribution of fracture modes did not vary significantly depending on the design of restoration and the type of material used.

CRediT authorship contribution statement

Rami S. Al Fodeh: Writing – original draft, Data curation, Conceptualization. **Omer S. Al-Johi:** Writing – review & editing, Data curation, Conceptualization. **Anas N. Alibrahim:** Writing – review & editing, Data curation, Conceptualization. **Ziad N. Al-Dwairi:** Writing – review & editing, Writing – original draft. **Nadin Al-Haj Husain:** Writing – review & editing, Writing – original draft. **Mutlu Özcan:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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