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ASSEMENT OF FRACTURE RESITANCE OF THERMOCYCLED AND NON THERMOCYCLED ENDOCROWN AND POST CROWN FABRICATED ON MAXILLARY PREMOLAR USING VITA ENAMIC. IN VITRO STUDY AND FINITE ELMENT ANALYSIS

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ABSTRACT

Objective: This study assessed fracture resistance of two different extensions (2-mm, 4-mm) endocrowns and post crown of maxillary premolar using Vita Enamic. Finite element analysis (FEA) was utilized to analyze biomechanical behavior.

Methods & Materials: Thirty sound maxillary premolars were collected, decapitated 2-mm supra cementoenamel junction (CEJ) then fixed into epoxy resin 2-mm below CEJ. Fixed premolars were endodontically treated and splitted into three groups depending on preparation into 2-mm, 4-mm extensions endocrowns and post crown as a control group. Vita Enamic was the construction material. After cementation, specimens were further sub-grouped according whether to be thermocycled or not then all specimens were loaded vertically till failure. Data statistically analyzed. 3D finite models were designed as simulation of endontically treated maxillary premolar restored with 2-mm, 4-mm extensions depth endocrowns and post crown. Vertical and 45˚ oblique loads of 300N were analyzed.

Results: showed that fracture resistance was the highest in 4-mm depth endocrown (1862.30±51.9) followed by 2-mm endocrown (1536.95 ± 44.2). Post crown recorded the lowest (1142.97±64.3). There was no statistical difference between thermocycled and non thermocycled except for post crown since thermocycled ones recorded lower results (907.12±42.7). In finite element analysis 4-mm endocrown produced lowest stresses with stresses diffusion toward dentin of cervical palatal area in all models.

Conclusion: it was concluded that endocrown is a promising alternative to post crown in maxillary premolar. Fracture resistance positively influenced by endocrown extension depth. FEA is a useful tool to predict failure mode.

KEYWORDS: Endocrowns, maxillary premolars, Fracture resistance, Finite element analysis.

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INTRODUCTION

Endodontically treated teeth with mutilated coronal hard tooth structure is vulnerable to biomechanical failure while successful rehabilitation depends upon successful type and quality of coronal restoration [(1)]. To restore badly mutilated teeth undergone endodontic treatment with either metal or fiber post aided with full coverage was the classical approached method. Which in turn would weaken the root structure due to expansion in radicular part [(2)].

Recently, there has been an increased perception of minimally invasive restorations due to their ability to maintain the integrity of the tooth structure. Furthermore, some researches adopted that the post no longer the key influencer in the success of endodontic therapy. However, it does contribute to the deterioration of the remaining tooth structure. A less intrusive and minimally invasive alternative restorative procedure is necessary, which entails minimum preparation and conserves the integrity of the remaining teeth [(2)] .

Endocrown restoration is a conservative treatment for restoring endodontically treated teeth (ETT). It is effective in sealing ability to root canal access and providing protection against bacterial invasion, which can negatively impact the long-term prognosis of an ETT. Furthermore, in the event of an endodontic failure, re-intervention can be more readily executed [(3, 4)].

Endocrown was pioneered by Pissis as a monoblock restoration in which the core with no need for a post. Porcelain was the first fabricant material aiming with to enhance light transmission and thus finally aesthetic characteristics [(5)].

Bindl and Mormann further developed this approach by studying severely damaged coronal structures of molars and premolars that were reduced in height and prepared with a circular equigingival butt edge. These teeth were then restored using Computer Aided Design/Computer Aided Manufacture (CAD-CAM) restorations [(6)].

After endodontic therapy premolars suffering from higher risk of fracture because of its anterior position to molars and posterior position to incisors. A debate exists regarding the most suitable restoration material capable of restoring both esthetics and function [(7)]. Vita Enamic was the selected material aiming to enhance both mechanical and optical properties of restored tooth. Vita Enamic is a hybrid ceramic that have two 3-dimensional network structures interpenetrating one to another; the dominant fine-structure feldspar ceramic network (86% by weight or 75% by volume) is strengthened by a polymer network consisting of methacrylate polymer (14% by weight or 25% by volume) [(8)].

The aim of our study was to investigate the biomechanical characteristics of maxillary premolars that have had endodontic treatment and were restored with endocrowns of two varying depths (2-mm, 4-mm). To compare these restorations with post-retained full coverage utilizing Vita Enamic. Assessing the efficacy of different treatment plans for maxillary premolars.

The null hypotheses of this in-vitro study state that varying endocrown extensions within the pulp chamber of a maxillary premolar or when treated with post crown do not exert a significant impact on fracture resistance following thermocyclic fatigue.

MATERIALS AND METHODS

Ethical regulations: The study received approval by the Research Ethics Committee of the Faculty of Dentistry, Minia University, under the reference number (91) term (653) of the year 2022.

1- Selection and sterilization of specimens

A total of thirty maxillary premolars with two root canals were extracted due to periodontal or orthodontic reasons. Gathered teeth were examined, teeth with widely curved roots were excluded. Selected teeth were with close dimensions at coronal and root length. Purification was carried out by nylon brush and pumice with low-speed handpiece.

This process involved the removal of calculus and soft tissue then left at room temperature for 15 minutes in a solution of 5% sodium hypochloride. Prior to the investigation, the teeth were maintained hydrated at room temperature in normal saline.

2-Decapitation and fixation of specimens

The crowns of the teeth that were gathered were cut about 2 mm above the cementoenamel junction (CEJ) from the buccal surface using a bur with a double-faced diamond disc with adequate coolant. Finally, fixed vertically into the epoxy resin. This was performed to replicate the compromised state of a coronally mutilated premolar. Tooth remaining dimensions in a bucco-lingual: 6 ± 0.5mm; mesio-distal: 5.0 ± 0.5 mm, remaining tooth length of 15 ±1.0 mm and root length 13 ±1.0 mm.

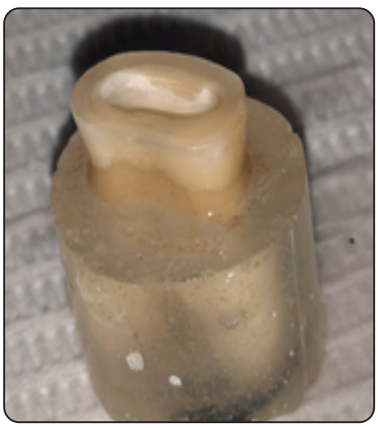


Fig. (1): decapitated fixed maxillary premolar

3-Endodontic therapy

The working length of the canals was defined using an x-ray aided by a size 10 K-file (Dentsply Maillefer, Switzerland). The mechanical debridement procedure was carried on by sequentially utilizing rotary protaper files of sizes S1, S2, F1, F2 and F3 using Fanta endomotor (china) at speed of 250 rpm. After each instrument change, the root canal was flushed with 2 ml of a 5% solution of sodium hypochloride. The root canals were dried using paper points and filled with Gutta-percha cones that were laterally condensed. A heated burnisher was employed to eliminate the protruding gutta percha. All procedures were performed by the same operator to standardize maneuver.

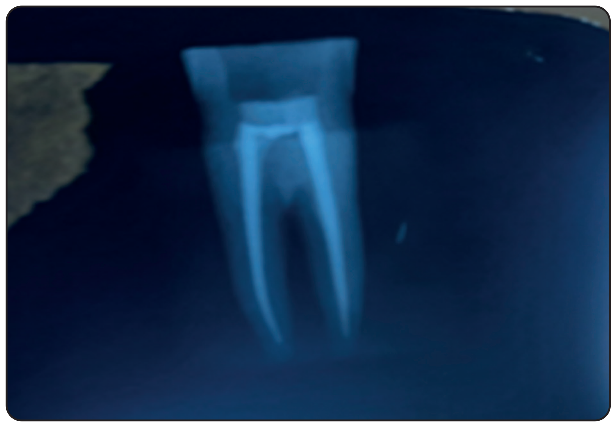


Fig. (2): X-ray of endodontically treated maxillary premolar after obturation

4-Classification of specimens

The thirty teeth were randomly classified into three groups according to way of preparation.

Group 1 contained 10 teeth assigned for 2-mm depth endocrown then Furtherly divided into two subgroups each contain 5 samples willing to be thermocycled or not.

Group 2 contained 10 teeth assigned for 4-mm depth endocrown then Furtherly divided into two subgroups each contain 5 samples willing to be thermocycled or not.

Group 3 contained 10 teeth assigned for post crown then Furtherly divided into two subgroups each contain 5 samples willing to be thermocycled or not.

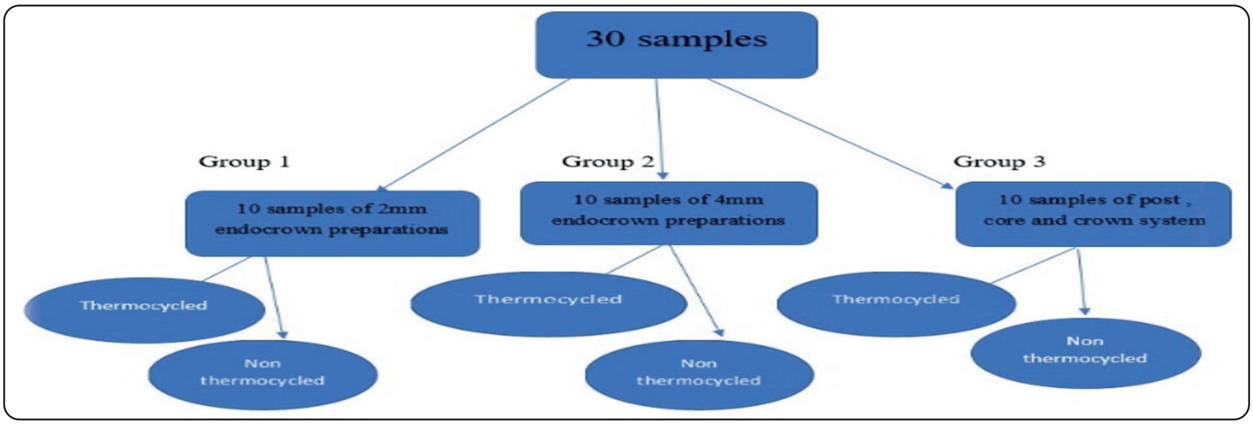


Fig. (3): study of factorial design

5- Endocrown space preparation

After endodontic treatment flowable composite resin (META BIOMED, Korea) was used to seal coronal part. A low-speed handpiece (Strong, South Korea) was linked to the micromotor. A cylindrical-conical diamond bur was conducted at a speed of 40000 rpm until a homogeneous pulpal depths were obtained with intermittent cooling during preparation to preserve the integrity of the teeth.

6- Preparation of post space.

Gate glidden boxes size 1, 2 were utilized to eliminate gutta percha up to 5- mm depth intra-radicular and 5-mm extruding coronally. Radicular walls were widen with reamer (Harald Nordin, Switzerland) then glassix drills size 2. Fiber posts (Nordin Glassix, Switzerland) taper 1.20 were utilized. The prepared space was treated with universal adhesive bond (bisco, all bond universal USA). After curing posts were cemented by Charmcore dual cured resin (DentKist, South Korea). 5-mm core was built with incremental flowable resin application and circumferential shoulder margin of 90 degrees was created on axial walls.

7- Fabrication of restorations (endocrowns, crowns)

The prepared teeth in acrylic resin blocks, were firmly attached to the scanning tray. They were then scanned using a Vinyl scanner (Smart Optics, Germany) in order to capture multiple images of preparation.

CAD/CAM software (exocad, DentalCAD Software) was used for designing the endocrown and full coverage restorations. Data file of restoration type, margins, wall thickness and cement space was sent to the milling machine unit.

Imes icore – 350i PRO (Germany) CAD/CAM milling system was utilized in fabrication of 10 units of 4-mm endocrown, 10 units of 2-mm endocrown and 10 units of crown restorations.

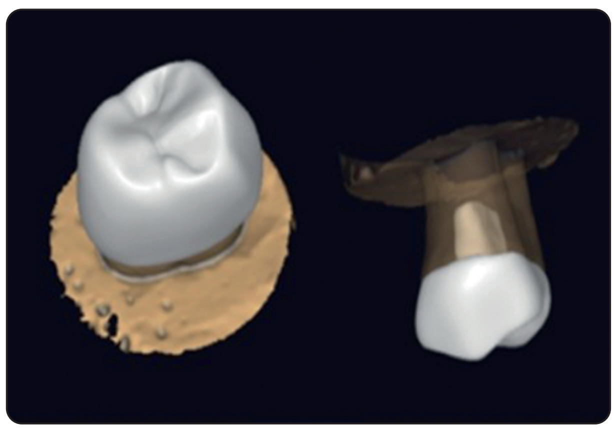


Fig. (4): full coverage and endocrown design with aid of exocad.

8- Cementation

The fitting surfaces of endocrown went through etching using a hydrofluoric acid (HF) solution with a concentration of 9.0% (Bisco, INC, USA) for a duration of 60 seconds. It was then washed for 60 seconds and subsequently dried for 30 seconds. The etched surfaces were silanated (Porcelain Primer, Bisco, INC, USA) and left to dry for 60 seconds [9] .

Tooth surfaces were treated with all bond universal (Bisco, INC, USA), light cured and cemented to corresponding restoration using dual cured resin (DUO-LINK UNIVERSAL, Dual Cured, USA). Any remaining cement was removed using a micro brush [9] .

9- Thermocycling fatigue

Five specimens from each primary group thermocycled in an automated thermocycling equipment for 5000 cycles. The process was executed using a Thermocycler (Thermocycler, SD Mechatronik, Feldkirchen-Westerham, Germany).

10- Fracture resistance

The specimens were placed in a vertical position on the central depression of their occlusal surfaces using a universal testing machine (specifically, the Instron type 3345 universal testing equipment, England). The loading piston was aligned precisely along the longitudinal axis of the specimens using a 5 mm diameter steel ball. The machine was operated at a thrust speed of 0.5 mm/min.

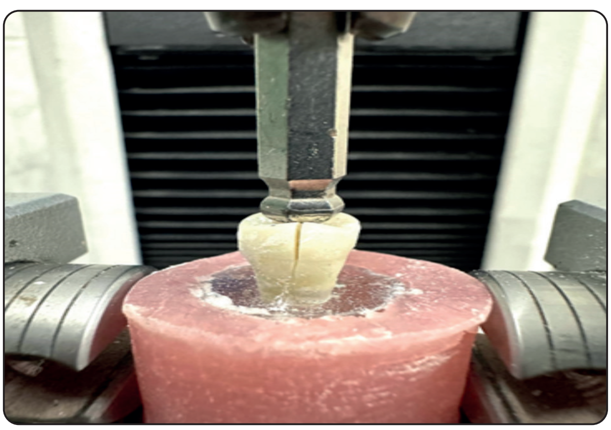


Fig. (5): Shows tooth under load to measure fracture resistance.

Finite element analysis (FEA)

1- Creation of (FEM) model

Intact maxillary premolar was scanned by Vinyl scanner (Smart Optics, Germany). The resulting data was then transformed into Digital Imaging and Communications in Medicine (DICOM) format and put into an interactive medical image control system.

Two models of the maxillary premolar were constructed based on the tooth preparation.

The first model: consisted of an endocrown with a 5mm occlusal clearance. A pulp chamber modulated to simulate a retentive cavity that extended 2mm.

The second model: consisted of an endocrown with a 5mm occlusal clearance. A pulp chamber modulation to simulate retentive cavity that extended 4mm deep.

Third model: consisted of intra pulpal post in each canal surrounded by cement. Each post extended into the coronal part and surrounded by flowable composite core material with 2mm height tooth structure

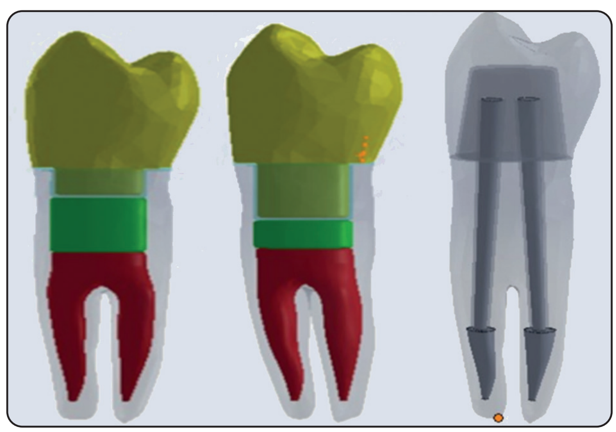


Fig. (6): Represents 2-mm depth endocrown, 4-mm depth endocrown and post retained full coverage models.

2- Determining the characteristics of materials

The study assumed that all materials were homogeneous, isotropic, and linearly elastic

The table (1) provided the values of the modulus of elasticity and Poisson's ratio for the various component materials examined in the study.

TABLE (1) Material properties

Materials	Elastic Modulus (MPa)	Poisson ratio	References
Dentin	18,600	0.31	10
Gutta-percha	0.14	0.45	10
Resin cement	6000	0.27	10
Flowable resin	7000	0.25	10
Vita Enamic	**30,100**	**0.23**	**10**

3-Simulation of vertical and oblique loads

A simulated vertical load of 300 N indicating medium biting force, was applied concurrently with the registration of mechanical characteristics at the indicated loading areas:

1. Both buccal and palatal cups at top and middle along vertical axis
2. A simulated force of 300 N was exerted at a 45◦ angle to the longitudinal axis of the tooth, simultaneously at the top, middle, and bottom of the palatal cup.

RESULTS

The data were validated, encoded by the researcher, and analyzed using IBM-SPSS 24*.. An ANOVA test was conducted to assess the mean differences of continuous variables with more than two categories. Post-hoc test was calculated using Bonferroni corrections. A p-value equals or less than (0.05) was deemed significant.

Results showed that:

- The 4mm endocrown had the greatest average fracture test value (1862.30 ± 51.9), whereas the 2mm endocrown had the second highest value (1536.95 ± 44.2). The post and core crown resulted in the lowest average fracture value, measuring (1142.97 ± 64.3). (Table 2).
- All specimens subjected to thermocycling remained intact without any noticeable signs of failure.
- The thermocycled 4-mm and 2-mm endocrowns (1807.98 ± 44.6) and (1480.89 ± 79.7) did not exhibit any statistically difference compared to the non-thermocycled ones. The thermocycled

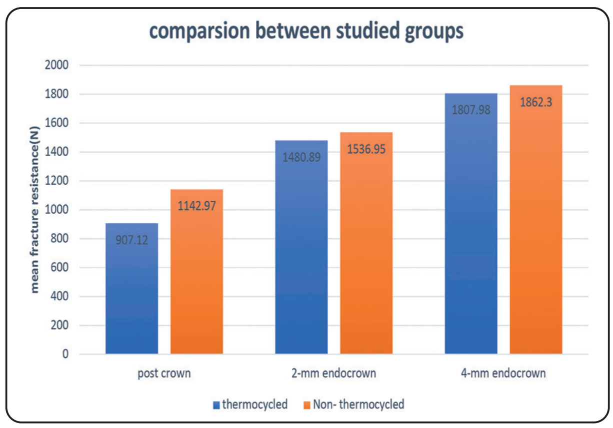


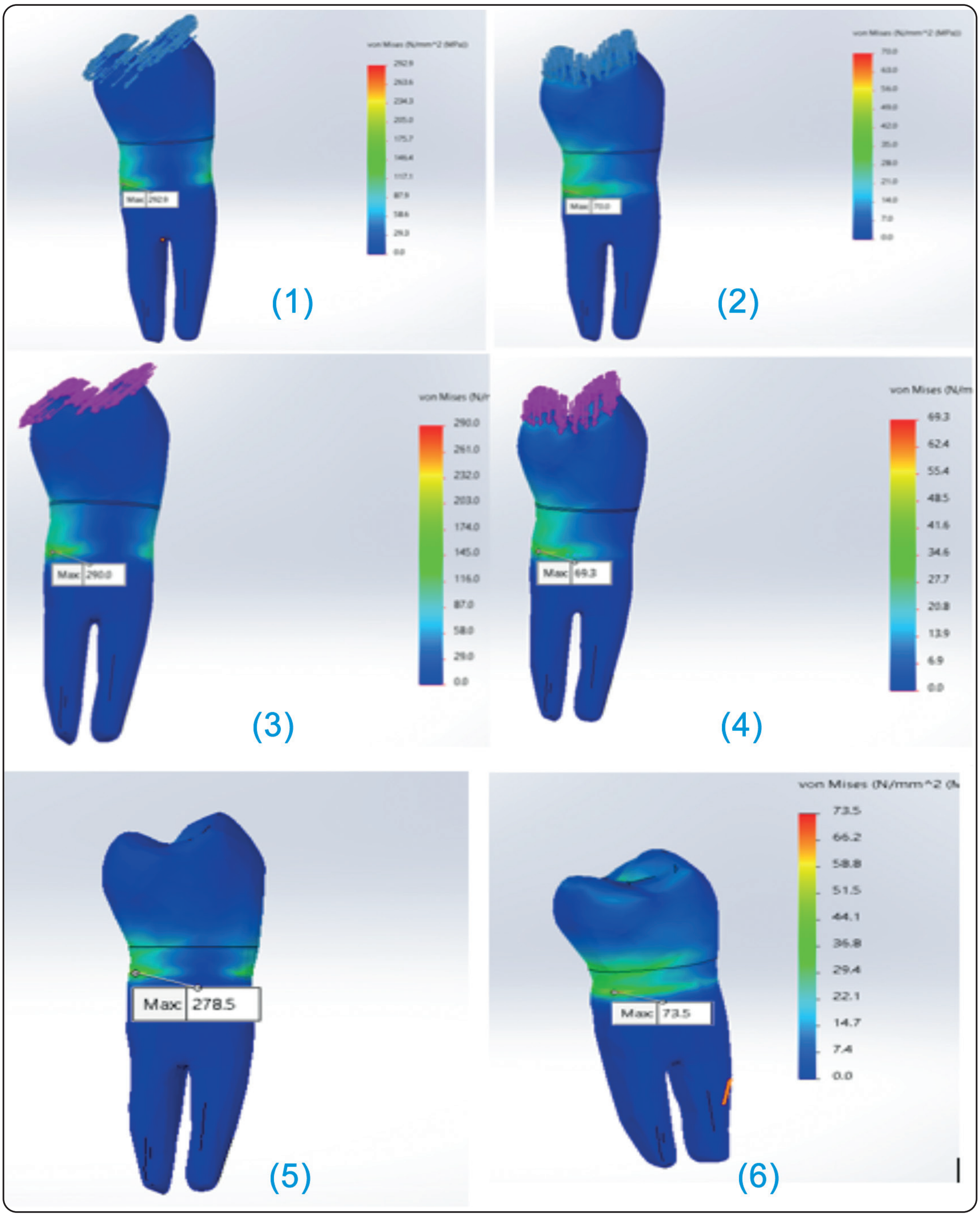
Fig 7: histogram shows comparison between studied Groups endocrown and post retained full coverage models.

TABLE (2) Statistical analysis of recorded fracture resistance at all studied groups.

Fracture Resistance (N)	Post/Core Crown (n = 5)	2-mm Endo-crown (n = 5)	4-mm Endo-crown (n = 5)	P-value
Thermocycled	907.12 ± 42.7	1480.89 ± 79.7	1807.98 ± 44.6	< 0.001*
• **P-value****	I vs. II < 0.001	II vs. III < 0.001	I vs. III < 0.001	
Non-Thermocycled	1142.97 ± 64.3	1536.95 ± 44.2	1862.30 ± 51.9	< 0.001*
• **P-value****	I vs. II < 0.001	II vs. III < 0.001	I vs. III < 0.001	

ANOVA test was used to compare the mean difference between groups

*****Post-hoc test was used for pairwise comparison with Bonferroni correction***



Fig, (8): Graphical representation of maximum von mises stress values for 2-mm and 4-mm endocrown Models

1-An assembled model of 2-mm endocrown under oblique load showing area of high stresses

2- An assembled model of 2-mm endocrown under vertical load showing area of high stresses

3- An assembled model of 4-mm endocrown under oblique load showing area of high stresses

4- An assembled model of 4-mm endocrown under vertical load showing area of high stresses

5- An assembled model of post crown under oblique load showing area of high stresses

6- An assembled model of post crown under vertical load showing area of high stresses post and core crown (907.12 ± 42.7) exhibited a statistically significant difference compared to the non-thermocycled one. Displayed in (Table 2)

Finite results:

- Under vertical and oblique loads all models showed accumulation of maximum stresses along palatal side.
- Mainly at dentin of CEJ region with coronal involvement observed for the root
- 4-mm endocrown had lowest stresses compared to 2-mm endocrown and post crown.
- Post crown transferred the highest stress compared to other groups.
- The peak of von mises stress (VMS) was recorded by dentin followed by vita Enamic while the lowest von mises stress (VMS) was recorded by Flowable resin.
- Failure index (FI): is the proportion of a component's material strength to the maximum produced stress in the component. When FI lower than one failure of concerned component happens [11].
- The maximum von mises stress (VMS) was below compressive strength in all models under vertical axial load.
- Oblique loads were higher than corresponding values resulted axially.

TABLE (3) Shows von mises stress of different components.

	Vita Enamic		Resin Cement		Flowable Resir		Dentin		Post	
	Vertical	Oblique	Vertical	Oblique	Vertical	Oblique	Vertical	Oblique	Vertical	Oblique
2 mm	37.1	112.7	27.1	83.2	11.6	42.8	70	292.9		
4 mm	36.3	101.7	28.1	81.2	7.1	21.4	69.3	290		
Post	53.1	160.2	25.5	80.3	17.7	49.5	73.5	278.5	5.5	17.1

DISCUSSION

Endocrown utilization in Premolars is considered a controversial question needs to be answered. Endocrown was approved as a favorable, reliable and promising restoring method after endodontic treatment of molars and premolars by **Otto and Mormann**, **Belleflamme et al.** [12, 13]**.** On the other hand, many studies did not recommend endocrown as an alternative to full coverage in case of badly destructed premolar. Clarifying their claim with inadequate tooth structure would be available for adhesion. In addition to the need for more mechanical retention betterly provided with crown system by **Schmidlin PR** [14]**.** Other studies demonstrated that there was no distinct difference between full coverage and endocrown carried by **Hamdy A et al, Guo J.** [15, 16]

This study found a significant discrimination between the post and core crown system and the endocrown. Endocrowns with a depth of 4-mm and 2-mm exhibited greater fracture resistance compared to complete coverage therefore null hypothesis was rejected.

It was hypothesized that the creation of a ferrule reduces the amount of tooth structure required for bonding. Enamel is more preferable than dentin for bonding. Another factor contributing to the increased fracture resistance of endocrowns is the typically thicker occlusal layer, in which ranges from 3 to 7 mm. A research adopted that the strength of ceramic crowns is positively correlated with the thickness of the occlusal surface. [17]

In clinical observations, it was shown that the typical bite force in the maxillary premolar region is 450 N while during clenching, the occlusal force can reach up to 660 N, whereas the highest known human masticatory forces range from 900 to 1000 N [10]. According to the findings, maxillary premolars that were intact broke when subjected to a force around 1121-1124.6 N. [18]

The study discussed the ability of 4-mm and 2-mm depth endocrowns to withstand forces similar to that of intact premolar compared to post crown. Additionally, the endocrown design has the capability to effectively repair both the structural integrity and the strength of a tooth that has had endodontic treatment and badly deteriorated.

This study evaluated vertical stresses effect on the biomechanical response when pulpal extension differed. **Gresnigt et al.** [17] adopted that axial loading provides a more direct assessment of the impact of inherent characteristics, such as modulus of elasticity and material thickness. The adhesion impact of the restoration on retention and bonding outcomes would be more closely associated with.

The material selected for this investigation was Vita Enamic (VE), A CAD/CAM material that aims to integrate the advantages of both ceramic and polymer materials. The low modulus of elasticity of this material appears to closely resemble the physical features of tooth structure, especially when compared to porcelain fused to metal. In addition to eliminating the requirement for heating after milling, this simplifies fabrication process and enhances dimensional accuracy [8].

The findings imply that there were no significant difference between the thermocycled and non-thermocycled 4-mm and 2-mm endocrown samples. This could be postulated to high bond strength of vita Enamic material to tooth structure.

Both dual-curing resin cements and traditional etch-rinse systems are widely recognized as the most reliable methods for bonding ceramic materials. Low modulus of elasticity 30.1 GPa, which is close to the dentin (16-20.3GPa). Absence of heating to complete crystallization process of ceramic also aids in reinforcing adhesion [19]. HF etching exposes hydroxyl groups, facilitating chemical interactions with the Silane coupling agent. This process enhances the surface energy and promotes better adhesion between resin cement and restorative material ([20, 21].

Thermocycling negatively impacted post crown leading to early failure. This effect may be linked to the phenomenon of water absorption by the composite resin cement. This phenomenon leads to the hydrolysis of the interfacial link between the filler of the ceramic and the polymer-based substance [22].

Stappert et al. [23] conducted a research which found that broad cement spacing widths during temperature changes can speed up the degradation of marginal cement material and reduce the strength of a ceramic restoration by increasing the dissolution of fillers. The marginal adaption of ceramic onlays decreases as a result of increased chemical wear, thermal cycling, and loading fatigue. Thermocycling may have led to hydrolysis of the silane, resulting in the deterioration of the chemical link between the resin cement and the ceramic [24].

These findings suggest that increasing the extension depth has a beneficial effect on fracture resistance. Specifically, a greater intra-pulpal depth is associated with higher fracture resistance. This may be supported by the wide surface area that was accessible for bonding, as well as the enhanced retention through macro-mechanical friction [25].

According to **Fages M, et al. and Debbabi et al**.[26 ,27], it has been proposed that the depth of the cavity should be a minimum of 3.0mm. Additionally, a greater extension of the pulp chamber is believed to result in improved mechanical qualities.

In addition, **Mahgoub, K.Y.A et al.** [28] found that increasing the preparation depth in maxillary premolars leads to a considerable improvement in fracture resistance.

Conversely, a research conducted by **Gaintantzopoulou M and ElDamanhoury H.**[29] yielded contradictory findings. The researchers assessed the impact of different depths of intra-radicular extension of endocrown using acrylic resin teeth. The samples were scanned, endocrowns were created utilizing the polymer infiltrated ceramic network materials (Vita Enamic and Vita Zahnfabric). The findings of this study demonstrated negative impact of the final restoration with more intra-radicular extension.

In their study, **De Kuijper et al**. [30] found that both extension and outline did not have a significant influence on fracture load.

The study found that the post and core crown system had the lowest average fracture resistance value, with a mean value of (1142.97 ± 64.3). In comparison, both the 2-mm and 4-mm endocrowns had higher fracture resistance values of (907.12 ± 42.7).The superior fracture resistance of endocrowns compared to crowns supported by post can be attributable to the greater occlusal thickness of the ceramic material, typically ranging from 3 to 7 mm.

Mormann et al.[6] found that the fracture resistance of all ceramic restorations rises as the occlusal thickness increases. The fracture resistance of the Endocrown is twice as high when the occlusal thickness is raised from 1.5mm to 5.5mm.

Chang, CY et al. [25] hypothesized that the conventional crown's weaker fracture resistance compared to endocrowns might be attributed adequate ferrule creation. When preparing a ferrule, there is a risk of damaging the enamel and dentin tissues of the tooth. However, when preparing endocrowns with a cervical sidewalk, the coronal enamel and dentin tissues are preserved. This preservation is important for strong bonding with the restoration, which increases resistance to fracture.

Several studies advocate for the use of post and core with complete coverage rather than endocrown. The studies attributed the inferior performance of endocrown to issues related to bonding within the root canal. Furthermore, the deterioration of the resin-dentin interaction over time is unavoidable. The unique structure of the root canal amplifies additional considerations during the application of adhesive, including the regulation of moisture and management of the smear layer - **Mjor IA** [31].

Also **Bindl et al** in a 7-year-long prospective trial using about eighty six endocrowns seventy of them were molars while the rest were premolars. Calculating success rate for both, molars were with the higher percentage therefore, authors concluded that endocrowns looked to be inadequate for premolars. [32]

Finite results represented with more stress generated from 2-mm endocrown compared to 4-mm endocrown which in turn support our laboratory study.

The most significant stresses were recorded and accumulated in the cervical area of the tooth, which may be the contributing cause of increased occurrence of unfavorable failures.

The validity of Vita Enamic as an endocrown was demonstrated by the fact that the maximal stress produced (112.7 MPa) remained below its flexural strength (135.8MPa). [33]

The maximum value of VMS in dentin was higher in the models compared to the vita Enamic material. Results were also supported by **Aboel-Fadl.AK et al.**[34] when compared stress distribution in maxillary premolar restored by different endocrown depths to post-retained full coverage with aid of finite elements analysis. Results showed the further the intrapulpal depth, there was a decrease in stress transfer under vertical force. It was concluded that endocrowns are a viable alternative to the postcore and crown system in maxillary premolars.

Maghami.E et al [33], Compared between angles of convergence, restoration depth and material type on stress distribution using finite element analysis. Three different angles were used (6, 12, 20) also two different depths and materials (3.1, 4.1) (polymer infiltrated ceramic, lithium disilicate). Results demonstrated that preparation depth is the major influencer in stress distribution of ceramic crown. **Mei.ML et al**. [35] reported that on both axial and oblique forces finite models generated high forces on adjacent dentin.

CONCLUSION

Bearing in mind the limitation of the study the following can be drawn

1. Endocrowns offers promising alternative to post retained full coverage in restoring badly destructed coronal tooth structure of maxillary premolar.
2. Fracture resistance affected positively by extension depth in case of endocrown but with more catastrophic failure.
3. Vita Enamic could be an ideal material in endocrown fabrication but not as a full coverage.
4. FEA could be a helpful tool besides in vitro studies to analyze stress distribution.

REFERENCES

1. El-Farag, S. A. A., Elerian, F. A., Elsherbiny, A. A., & Abbas, M. H. (2023). Impact of different CAD/CAM materials on internal and marginal adaptations and fracture resistance of endocrown restorations with: 3D finite element analysis. BMC Oral Health, 23(1), 1-18.
2. Al-Dabbagh, R. A. (2021). Survival and success of endocrowns: A systematic review and meta-analysis. The Journal of prosthetic dentistry, 125(3), 415-e1.
3. Taha.D, Spintzyk.S, Schille.C. (2018). Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness. Journal of Prosthodontic Research, 62;293-294.
4. da Fonseca GF, de Andrade GS, Dal Piva AMO, Tribst JPM, Borges ALS. (2018). Computer-aided design finite element modeling of different approaches to rehabilitate endodontically treated teeth. J Indian Prosthodont Soc. (4):329-335.
5. Pissis, P. (1995). Fabrication of a metal-free ceramic restoration utilizing the monobloc technique. *Practical periodontics and aesthetic dentistry: PPAD*, *7*(5), 83-94.
6. Bindl A, Mörmann WH.(1999). Clinical evaluation of adhesively placed Cerec endo-crowns after 2 years — preliminary results. J Adhes Dent,1(3): 255-265.
7. Lise.DP, Van Ende.A, De Munck. J. (2017). Biomechanical behavior of endodontically treated premolars using different preparation designs and CAD/CAM materials. Journal of Dentistry (59) ;54-61.
8. Sağlam G, Cengiz S, Karacaer Ö. (2020). Marginal adaptation and fracture resistance of feldspathic and polymer-infiltrated ceramic network CAD/CAM endocrowns for maxillary premolars. Niger J Clin Pract. 23:1-6.
9. Magdy, H., El Mahallawi, O. S., & Nabil, O. (2023). Efficacy of preparation design on fracture resistance of hybrid-ceramic endo-crown on premolars: An in vitro study.
10. Shams, A., Sakrana, A. A., Abo El-Farag, S. A., & Özcan, M. (2022). Assessment of biomechanical behavior of endodontically treated premolar teeth restored with novel endocrown system. Eur J Prosthodont Restor Dent, 30(1), 20-35.
11. Maghami, E., Homaei, E., Farhangdoost, K. (2018). Effect of preparation design for all-ceramic restoration on maxillary premolar: a 3D finite element study. journal of prosthodontic research, 62(4), 436-442.
12. Otto T, Mormann WH. (2015). Clinical performance of chairside CAD-CAM feldspathic ceramic posterior shoulder crowns and endocrowns up to 12 years. Int J Comput Dent;18:147-61.
13. Belleflamme, M. M., Geerts, S. O., Louwette, M. M., Grenade, C. F., Vanheusden, A. J., & Mainjot, A. K. (2017). No post-no core approach to restore severely damaged posterior teeth: An up to 10-year retrospective study of documented endocrown cases. *Journal of Dentistry*, *63*, 1-7.
14. Schmidlin PR, Stawarczyk B, DeAbreu D, Bindl A, Ender A, Ichim IP. (2015). Fracture resistance of endodontically treated teeth without ferrule using a novel H-shaped short post. Quintessence Int. 46:97-108.

15. Hamdy, A. (2015). Effect of full coverage, endocrowns, onlays, inlays restorations on fracture resistance of endodontically treated molars. J Dent Oral Hyg, 5, 2.

16. Guo J, Wang Z, Li X, Sun C, Gao E, Li H. (2016). A comparison of the fracture resistances of endodontically treated mandibular premolars restored with endocrowns and glass fiber post- core retained conventional crowns. J Adv Prosthodont. 8:489-93

17. Gresnigt M.M, Özcan M, van den Houten M.L, Schipper L & Cune M.S. (2016) Fracture strength, failure type and Weibull characteristics of lithium disilicate and multiphase resin composite endocrowns under axial and lateral forces. Dental materials. 32(5):607-614.

18. Hidaka O, Iwasaki M, Saito M, Morimoto T. (1999).Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. J Dent Res.78:1336–44

19. Elbasty R, Eltannir A, Shaker A. (2017). Vertical marginal gap distance and retention of different cad/cam ceramic endocrowns with two preparation designs. Egyptian Dental Journal. 63(1):755-767

20. Özel Bektas, Ö., Eren, D., Herguner Siso, S., Akin, G.E. (2012). Effect of thermocycling on the bond strength of composite resin to Bur and laser treated composite resin. Lasers.Med.Sci. 27,723–728.

21. Fayyazi A, Habibi L, Heidari B, Tavakolizadeh S. (2023). Tensile Bond Strength and Retention of Three Types of Ceramic Endocrowns. J Dent (Shiraz). 24(1):34-40.

22. Porto, T. S., Roperto, R. C., Akkus, A., Akkus, O., Teich, S., Faddoul, F. F.& Campos, E. A. D. (2018). Effect of thermal cycling on fracture toughness of CAD/CAM materials. *Am J Dent*, *31*(4), 205-10.

23. Stappert CF, Chitmongkolsuk S, Silva NR, Att W, Strub JR. (2008). Effect of mouth-motion fatigue and thermal cycling on the marginal accuracy of partial coverage restorations made of various dental materials. Dental materials. 1; 24(9):1248-57.

24. Monticelli F, Toledano M, Osorio R, Ferrari M. (2006). Effect of temperature on the silane coupling agents when bonding core resin to quartz fiber posts. Dental materials. 22(11):1024-8.

25. Chang.CY, Kuo.JS, Lin.YS, Chang. YH. (2009). Fracture resistance and failure modes of CEREC endo-crown and conventional post and core -supported CEREC crowns. J Dent Sci. 4(3):110-117.

26. Fages M, Bennasar B. (2013). The endocrown: A different type of all-ceramic reconstruction for molars. J Can Dent Assoc. 79:140.

27. Debbabi I, Nouira Z, Saafi J, Harzallah B, Cherif M. (2018). “ENDOCROWN”: A Reliable Alternative to Restorate RCT Molar! – Two Case Reports. Adv Dent & Oral Health. 9(5):555774.

28. Mahgoub, K. Y., Abofadle, A. K., & Mina, R. K. (2023). Influence Of Two Different Intrapulpal Depths On Fracture Resistance Of Endocrowns Restoring Maxillary Premolar Teeth Using Vita Enamic.(In Vitro study). Egyptian Dental Journal, 69(3), 2029-2034.

29. Gaintantzopoulou MD, El-Damanhoury HM. (2016) Effect of preparation depth on the marginal and internal adaptation of computer-aided design/computerassisted manufacture endocrowns. Oper Dent. 41:607-16

30. de Kuijper, Maurits CFM, Cune MS, Tromp Y. (2014) Cyclic loading and load to failure of lithium disilicate endocrowns; influence of restoration extension in pulp chamber and the enamel outline. J Operative Dentistry. 39(6): 595-602.

31. Mjor IA, Smith MR, Ferrari M, et al. (2001).The structure of dentine in the apical region of human teeth. Int Endod J;34(5):346–353.

32. Bindl A, Richter B, Mörmann WH. (2005).Survival of Ceramic Computeraided Design/Manufacturing Crowns Bonded to Preparations with Reduced Macroretention Geometry. Int J Prosthodont 18:219-224.

33. Maghami.E, Homaei.E, Farhangdoost.K. (2018). Effect of preparation design for all-ceramic restoration on maxillary premolar: a 3D finite element study. Jornal of prosthodontic research. 436-442.

34. Aboel-Fadl.AK, Adelel-Desoky.M. (2017). influence of endocrown pulpal extension on stress distribution of endodontically treated maxillary premolar. Athree dimensional finite element analysis. Egyptian dental journal. 63, 3895:3905.

35. Mei.ML,Chen.YM,Li.H. (2016) Influence of the indirect restoration design on the fracture resistance: a finite element study. BioMed Eng OnLine 15:3