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# Fracture Resistance of CAD/CAM Fabricated Polyetheretherketone (PEEK) Endocrowns and Post Retained Crowns with Two Preparation designs

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Restorative Dentistry
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## *ABSTRACT*

**Purpose**: The aim of this study was to assess the fracture resistance of PEEK endocrowns and post-retained PEEK crowns with two preparation designs (ferrule and without ferrule). **Materials and methods:** Eighty sound human mandibular first premolars were selected. Teeth were divided into 4 main groups (n= 20): Group1: Were assigned for endocrown preparation with Butt joint. Group 2: Were assigned for endocrown preparation with Shoulder finish line. Group 3: Were assigned for PEEK post & core preparation without ferrule. Group 4: Were assigned for PEEK post & core preparation with ferrule. Endocrowns of both Group 1 and Group 2 were made of PEEK material veneered with composite. Both Group 3 and Group 4 were covered with PEEK crowns veneered with composite. All Restorations either PEEK post & cores or endocrowns and final crowns were sandblasted with 110 Mm aluminium oxide. Finally, cemented with self-adhesive resin cement (G-Cem cement). **Results:** The highest mean value was recorded in Post & core with ferrule (above CEJ) (1262.29±65.02), followed by Endocrown with Butt Joint (1101.44 ± 81.7), then Endocrown with Shoulder finish line (890.99±75.42), with the least value recorded in Post & core without ferrule (below CEJ) (726.03±71.26). Statistically, ANOVA test showed a considerable difference between groups (p=0.00). Tukey's post hoc test showed a considerable difference between each 2 groups. **Conclusion:** It was concluded that the mandibular premolars that were restored by PEEK Post-cores covered with crowns which designed with ferrule recorded the highest fracture resistance load.

***KEYWORDS***

*PEEK, post and core, Endo crowns, Resin cement, Fracture Resistance.*

- Paper extracted from Master thesis titled "Fracture Resistance of CAD/CAM Fabricated Polyetheretherketone (PEEK) Endocrowns and Post Retained Crowns with Two Preparation designs"

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## INTRODUCTION

Rebuilding of endodontically treated teeth is considered a great task in restorative dentistry [1]. Extremely thin coronal remaining tooth structure has been developed after root canal therapy and preparation for crown. Several researches had proposed that the dentin in root canal treated teeth is appreciably different than dentin in teeth with vital pulps, where a protective feedback mechanism is lost when the pulp is removed and roots are more prone to fracture [2]. The success of this task depends on the type and the quality of the coronal restoration[3].

Many treatment protocols have been investigated to restore the teeth that have missed a significant part of their coronal structure. One of them is intra radicular dental post & core systems. The most commonly used post & core systems can be categorized into two main groups; one-piece cast post-core system and two parts system involving a ready-made manufactured post with composite core[4].

Traditionally, metal alloy post-core systems are the first choice for the restoration of the tooth in such condition. But, due to a large elastic modulus difference between metal alloys and dentine, an excessive functional stress concentration may occur around the post, leading to catastrophic root fracture [5]. According to preceding studies, when using a lower elastic modulus post material, such as fiber glass, a more advantageous stress distribution occurs.

Endocrown restorations are used as an alternative treatment protocol to post-core systems to restore the coronal portion of the mutilated teeth. Endocrowns, are monoblock restorations, prescribed as bonded overlay restorations consist of coronal portion and apical projection anchored to the pulp chamber space to achieve macro-mechanical retention, whereas micromechanical retention is achieved by the use of adhesive cementation. As the depth of pulp chamber and intracoronal extension increase, the micromechanical retention and dispersion of masticatory stresses increase [6].

Among the needs that motivated the researchers for endocrowns are: 1) minimizing the drilling inside the root canal, 2) preservation of root dentine, 3) decreasing the clinical steps and institution of dentine adhesive system [7].

Nowadays, a biocompatible organic thermoplastic polymer belongs to the PolyArylEtherKetone family, known as Polyetheretherketone (PEEK) [8], the manufacturer reveals that PEEK has a comparable compressive strength to that of dentin [9]. Additionally, its biocompatibility, proper mechanical strength, shock-absorbing ability, and a broad potentiality of fabrication processing incorporating milling and pressing make PEKK a desirable and excellent dental material for the construction of customized intraradicular dental post & core [10].

With the development of the CAD-CAM systems and the evolution of Cerec 3 system to the dental field, which has many developments over the Cerec 2 system [11]. This study aims to estimate the fracture resistance of endodontically treated teeth: effect of CAD-CAM PEEK post-core covered with full coverage PEEK crowns (veneered with composite) and endocrown restorations [12].

## MATERIAL AND METHODS

### Sample size calculation

1. A power analysis was designed to have adequate power to apply a two-sided statistical test of the research hypothesis (null hypothesis) that there is no difference between the groups regarding different measured parameters. By adopting an alpha ($\alpha$) level of 0.05 (5%), a beta ($\beta$) level of 0.2 (20%) i.e., power=80%, and an effect size (d) of (0.05) calculated based on the results of a previous study [13].
2. The predicted sample size (n) was a total of (80) samples. Sample size calculation was performed using G*Power version 3.1.9 and Steven K. Thompson equation was used to calculate the sample size [14].

**Tooth Collection and Preparation:**

Eighty mandibular anonymous premolars were collected following extraction from surgery department for orthodontic purpose or following severe periodontal problems. The research ethics committee approval of the Faculty of Dental Medicine for Girls, Al-Azhar University (REC) was obtained with code (REC-CR-21-01).

Endodontic treatment was performed in all teeth to receive PEEK CAD/CAM endocrown and post & core restoration.

**Specimen grouping:**

Eighty mandibular premolars teeth were grouped into four groups (n=20) according to the restoration type into:

Group 1: Were assigned for endocrown preparation with Butt Joint preparation.

Group 2: Were assigned for endocrown preparation with Shoulder finish line.

Group 3: Were assigned for post & core preparation without ferrule.

Group 4: Were assigned for post & core preparation with ferrule.

**Teeth disinfection and storage:**

Teeth were disinfected by immersion in 5% sodium hypochlorite for 15 minutes at room temperature. All teeth were disinfected with ultrasonic scaler with low power and under copious water and finally kept in saline solution at room temperature till its usage.

**Centralizing the teeth in the epoxy resin blocks:**

A specifically designed centralizing device was used to permit correct and exact centralization of the tooth during fabrication of epoxy resin blocks. The device consists of a cylindrical Teflon mold (2cm length and 2cm internal diameter) which constructed for holding the epoxy resin and the tooth inside.

**Removal of coronal tooth:**

Each tooth was sectioned perpendicular to the long axis (2 mm) coronal to the proximal CEJ, using a super coarse diamond disc by Computerized Numerical Control (CNC) milling machine (C.N.C Premium 4820, imes-icore, Eiterfeld, Germany) [13] (fig.1).

Figure (1) C.N.C Machine

**Endodontic treatment:**

K-file (#10) (Dentsply Maillefer, Switzerland) was used to check the patency of all root canals, the working length was positioned 1mm short of the apex. Rotary Protaper S1, S2, and F1 files were used to the working length, respectively while mounted in an S-Denti micro motor (ES-100) (Seoul, Korea), at a speed of 250 rpm. Irrigation with 5% sodium hypochlorite was done between the different files. All canals were obturated using the matched protaper gutta-percha cones by lateral compaction technique. Eugenol free resin sealer was used to avoid interference with the setting reaction of the resin cement. Finally, the excess gutta-percha was detached by heated instrument (cherry red) then a periapical radiograph was taken to ensure the obturation.

**Preparation of endocrowns with butt joint design:**

The endodontic access cavity was prepared with butt joint design using a tapered rounded

end diamond coated stainless steel bur (Chamfer Endmill) to eliminate undercuts with an 8-10 degrees internal taper in conjuction with 4 mm depth and wall thickness 2mm (fig.2).

**Preparation of endocrowns with shoulder finish line:**

The same steps as preparation of endocrowns with butt joint in addition to preparing shoulder finish line all around the tooth above CEJ with 1 mm and with thickness 1 mm maintaining 2 mm wall thickness (fig.2).

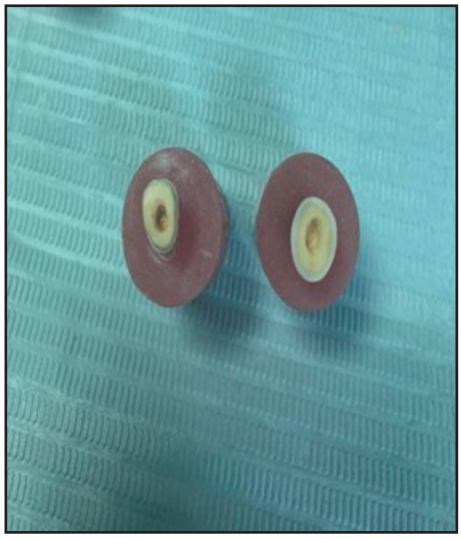

Figure (2) Endocrown preparation (butt joint & shoulder finish line)

**Preparation of CAD-CAM post-core space with ferrule:**

After finishing the endodontic treatment, Gates-glidden drills (Dentsply-Maillefer, Ballaigues, Switzerland) were used with rubber stoppers that were attached to the gates gliddens to standardize the length of the post and remove guttapercha from the canals. Then an impression of the post space preparation is made using a light-body addition silicon material (Zhermack, German) that was injected into the space of the root canal using a syringe. After that a plastic post (Anger G & A endolucent plastic post, EU) was inserted into the canal. In addition, preparing 1 mm shoulder finish line all around the tooth, placing it above CEJ within 0.5 mm. (fig.3)

Figure (3) (Preparing shoulder finish line above CEJ)

**Preparation of CAD-CAM post-core space without ferrule:**

The same steps as preparation of CAD-CAM post-core space (with ferrule) with preparing 1 mm shoulder finish line all around the tooth, placing it 0.5 mm below CEJ. (fig.4)

Figure (4) (Preparing shoulder finish line below CEJ)

**CAD-CAM Milling procedures:**

An anti-reflection scan spray (SCAN-LAC Spray. PROTECHNO Fabrica, Spain) was scattered and applied over the patterns (Mandibular premolar) which is a liquid lacquier for CAD-CAM scanning using Smart optics scanner (Smart optics scan box pro, Germany).

Each tooth was fixed over the scanning tray of the extraoral scanner (Smart Optics -Scan Box).

The fabrication data of the virtual image of the restorations was achieved by standard transformation language (STL) data format.

The CAD-CAM software (DWX -510 Milling Machine Roland DG corporation, Japan.) was started by choosing the suitable kind of restoration.

After the software program determined the suggested model of endocrown, some adjustments were done manually as the endocrown depth was 4 mm within the pulp chamber [10].

The STL file was forwarded to the milling unit to mill the endocrowns, post & cores and the full coverage crowns from PEEK blocks.

**Application of the composite veneer:**

After milling of all restorations for the selected prepared teeth of the 4 groups and checking their fit and reaching the full length inside the prepared canal (regarding the post and core restorations for both groups 3 & 4) and their marginal accuracy using periapical x-rays.

The milled PEEK endocrowns (for both group 1 & 2) and the full coverage crowns (for both group 3 & 4) were veneered manually with composite using visiolign material before their final cementation.

**Surface treatment to PEEK:**

The fitting surface of PEEK composite restorations were treated by 110 Mm $AL_2O_3$ Sandblaster, (PROTECHNO Fabrica, Spain). (Masel, USA) for 15 seconds at a pressure of 0.4 MPa and a distance of 10 mm perpendicular to the treated surface. Distilled water was used for cleaning the specimens for 60 s then dried by compressed air.

**Cementation procedures:**

The restorations were cemented by dual cure resin cement (G-Cem Capsules) under finger pressure using weight, then light activated at each surface for 20 seconds. Excess cement was removed immediately with a cotton pellet.

**RESULTS**

**Fracture Resistance Max. load (N)**

***A. Comparison between all groups***

The highest mean value was recorded in Post & core with Ferrule (above CEJ) (1262.29±65.02), followed by Endocrown with Butt Joint (1101.44 ± 81.7), then Endocrown with Shoulder finish line (890.99±75.42), with the least value recorded in Post & core without Ferrule (726.03±71.26). ANOVA test showed a statistically significant difference between groups (p=0.00). Tukey's post hoc test showed a substantial difference between each 2 groups (fig.5).

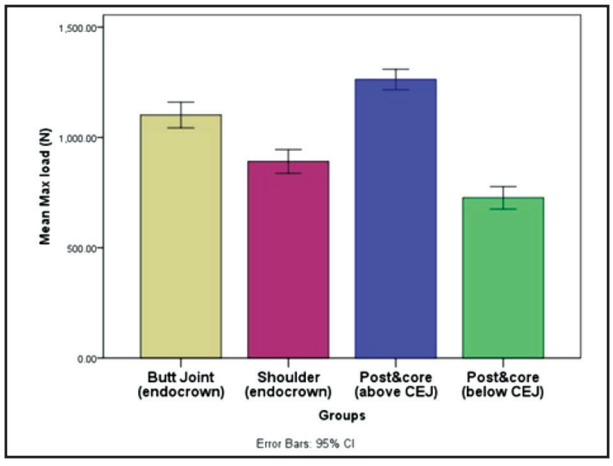


Figure (5) (Preparing shoulder finish line above CEJ)

### B-Comparison between endocrown types

The highest mean value was recorded in Endocrown with Butt Joint (1101.44±81.7), with the least value recorded in Endocrown with Shoulder finish line (890.99±75.42). Independent t test detected a significant difference statistically between groups (p=0.00) (fig.6).

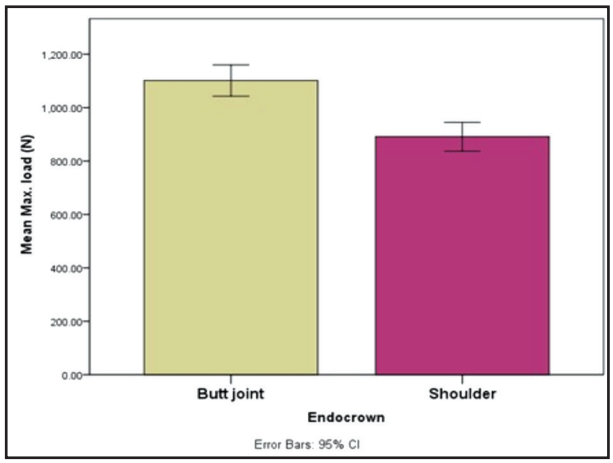


Figure (6) Bar chart illustrating resistance to fracture maximum load (N) in different groups.

### C-Comparison between Post and core types

The highest mean value was recorded in Post & core with Ferrule (above CEJ) (1262.29±65.02), with the least value recorded in Post & core without Ferrule (below CEJ) (726.03±71.26). Independent t test revealed a statistically significant difference between groups (p=0.00) (fig.7).

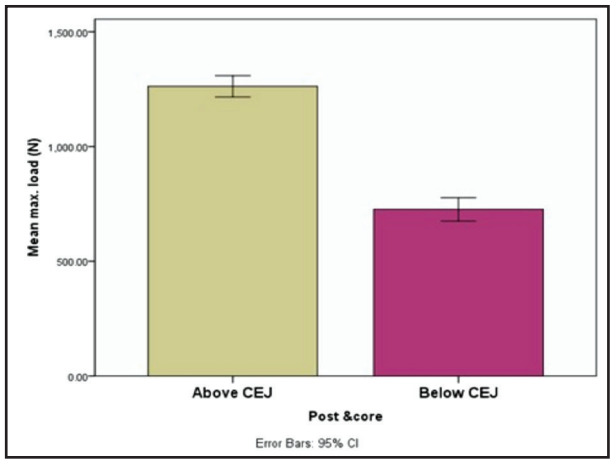


Figure (7) Bar chart illustrating resistance to fracture maximum load (N) in post & core groups.

## DISCUSSION

When considering the restoration of the devitalized endodontically treated teeth, dental materials should be able to replace this loss of substance in order to guarantee mechanical and functional properties, esthetics and coronal seal [15].

The fracture resistance of the devitalized mutilated teeth is related to many factors including the root canal treatment (risk of vertical root fractures), coronal issues (quality and quantity of remaining tissues and loading context), the type, design and the material of the restorations used to restore these teeth whether the classical approach of post and core systems (post material and size, core material, ferrule effect) or endocrown adhesive restorations ( either butt joint designs or with shoulder finish line designs) [15] .

Some in vitro studies reported that bonded all ceramic CAD-CAM endocrowns showed comparable fracture load values compared with conventional crowns. Several clinical case reports showed the potential of this restorative approach to provide adequate function and esthetics, even with compromised tooth integrity of non-vital premolars [16].

That's why the objective of this current in vitro study was to assess the fracture resistance of PEEK endocrowns and post-retained PEEK crowns with two preparation designs (ferrule and without ferrule). PEEK material is chosen in this study mainly for its low modulus of elasticity which is corresponding to that of dentin. Also, its ability to be sandblasted to achieve a strong and durable resin bond.

With recent developments of adhesive techniques, the benefit of adhesive restorations is that a macro retentive design is no longer a necessity if there are sufficient tooth surfaces for bonding. With the adhesive technique, creating a ferrule is a drawback because of loss of the natural tooth structure and enamel. Minimally invasive preparations to maintain a maximum amount of tooth structure

are considered the gold standard for restoring teeth. Endo-crowns strictly follow this rationale in consequence of a decay-orientated design concept [16]. Therefore, different preparation designs were chosen in this study.

In vitro investigations on prosthetic restorations should provide information that is closer to the clinical situation than testing material properties on standardized samples. Therefore, every effort was taken in the current study to mimic clinical situations as much as possible [16].

In this study, human natural teeth (mandibular first premolars) were used in an attempt to closely approximate the clinical situation, with respect to tooth properties and morphology [17]. The size of the selected teeth was standardized to minimize possible variations and errors usually associated with using human natural teeth in in-vitro studies [18]. For standardization of teeth preparations, a special milling machine (Centroid milling machine), was used for all the preparations of the 4 groups.

The milled PEEK endocrowns and the full coverage crowns were veneered manually with composite using visiolign material before their final cementation. unfortunately, PEEK does not meet the aesthetic needs [19]. Thus, the opacity and shade of the material involve the application of a veneering material.

The milled endocrowns were manually adjusted before cementation as the endocrown length was 4 mm inside the pulp chamber to enhance the surface area of adhesion and the retention of the restoration hindering their displacement from the root cavity under lateral stresses [10]. Finally, they were cemented using dual cure resin cement (G- Cem capsules). This cement was chosen in order to set on demand, also to resist microleakage and fewer desiccation and hydration problems.

Under the circumstances of this current study, group (4) mandibular premolars recorded the highest fracture resistance load that were restored by PEEK Post-cores covered with crowns which designed with ferrule followed by butt joint endocrowns (group 1).

These results are in agreement with a previous study, they concluded that post-core with 2mm ferrule supported CAD-CAM crown has a considerable higher mean value of fracture resistance than endocrown. This is possibly due to smaller surface area of adhesion of endocrown compared to post-core which has more contact area for adhesion between post and 2 mm ferrule that support crown [20].

A previous study is on the line with the results of this current study, they noted that the group of CAD-CAM polymer-infiltrated ceramic post-core recorded a significant higher fracture resistance value statistically. Enhancement of the fracture resistance of broad root canals can be achieved by using CAM-CAM post and core as a substitute to the usage of glass fiber post, relined with composite resin [21].

Another study is in agreement with the results of this study, they concluded that CAD-CAM PEKK post and core, with a lower elastic modulus than root dentin, showed comparably high failure resistance and a more favorable stress distribution than conventional post-core material. Although, fiberglass has a lower elastic modulus than metal, its elastic modulus is still several times higher than that of dentine [22].

On the other hand, these results are in disagreement with a previous study, they noted that the endocrown does not imply a higher mean value of fracture resistance than conventional crown with post-core. They found that the mandibular premolar had a smaller crown, which caused insufficient resistance forms of residual tooth tissue. Sufficient bonding area is crucial for the retention and stability of endocrown. A smaller pulp chamber area of mandibular premolars leads to a decreased bonding area and therefore to the decline of retention force. Moreover, the narrow neck of mandibular

premolar is more obvious, and the diameter of the root is smaller than that of the maxillary premolar, which might lead to poor stress transmission patterns from crown to root [23].

Another study is in disagreement with the results of this current study, they concluded that the endocrowns and traditional crowns with post and core restorations did not show a significant difference from each other. They clarified that the endocrowns recorded equivalent stress values as endocrown include both the crown and core that act as a single unit which minimize the effect of multiple interfaces that were found in conventional crown [24].

## CONCLUSION

It was concluded that post and cores fabricated from PEEK with ferrule design has the highest fracture resistance compared to the other tested designs: butt joint preparation of endocrowns, endocrowns with shoulder finish line and PEEK post and core without ferrule design which has the least value of fracture resistance. Moreover, PEEK endocrowns with both designs (butt joint and shoulder) were successfully tested to maintain the endodontically treated teeth.

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## RECOMMENDATIONS

In the further studies, we recommended that further long-term clinical evidence is required to demonstrate the use of this material as a substitute for conventional ceramic or metal ceramic crown for endodontically treated teeth.

The fracture resistance should be investigated on chewing simulators to accurately assess the dynamic loads.

## DECLARATION STATEMENT

Authors declare no conflict of interest.

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