Original Article

Comparative evaluation of incorporation of ferrule in premolars endocrown designs to check any alterations in their fracture resistance: A pilot study

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Abstract

Introduction: Endocrown preparation of endodontically treated teeth as final restoration has been extensively studied for different teeth. Bindl *et al*. questioned the application of endocrowns for premolars due to the pulp chamber space's smaller dimensions, which diminish bonding surface area. The addition of ferrule into the endocrown preparations of premolars has not been extensively studied.

Aims and Study Design: Comparative evaluation of incorporation of the ferrule in premolars endocrown designs to check any alterations in their fracture resistance.

Materials and Methods: The sample consisted of 40 maxillary first premolars without cracks or caries, extracted for orthodontic or periodontal purposes. The teeth were individually mounted with cold-cure acrylic resin. Group A: Composite endocrown without ferrule and Group B: Composite endocrown with ferrule. An endocrown former was prepared with elastomeric polyvinyl siloxane material (GC Exaclear). Endocrowns were then prepared with dual-cure core build-up composite-Core-x flow (Dentsply Maillefer, Switzerland) using the endocrown former so that morphologically, they all were almost identical. Endocrowns are cemented by dual-cure resin cement following manufacturer instructions. The fracture resistance of endocrowns with and without ferrule was evaluated and compared.

Results and Observations: The data were tabulated in Microsoft Excel and analyzed with SPSS version 24 software. The variables were presented with mean, standard deviation, and independent *t*-test. The $P \leq 0.05$ is considered statistically significant. Group B (with ferrule) showed higher fracture resistance (622.06 N) than Group A (537.59 N) (without ferrule). Independent *t*-test showed that the difference was statistically significant ($P = 0.008$).

Conclusion: Comparing the failure load findings, it could be concluded that ferrule-containing endocrown needed greater loads than ordinary endocrown restorations for failure.

Keywords: Dual-cure composite core build-up material; dual cure resin cement; endocrown; ferrule; fracture resistance

INTRODUCTION

Endodontically treated teeth can be restored using various treatment techniques and materials. The introduction of adhesives has reduced the dependence of restorations on macromechanical retention.[1] With sufficient surface area for adhesion, the requirement for a post and core to support crowns is principally decreased.[2] Therefore, in modern dentistry, posts are used only when other conservative treatments are inefficacious.[3,4] The residual tooth structure and available adhesive surface area are very important for decision-making and long-term success

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Date of submission : 10.05.2024
Review completed : 23.05.2024
Date of acceptance : 23.05.2024
Published : 08.07.2024

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_277_24

How to cite this article: Pal PP, Mazumdar D, Bera S, Kar S, Sahay D, Chowdhuri K. Comparative evaluation of incorporation of ferrule in premolars endocrown designs to check any alterations in their fracture resistance: A pilot study. J Conserv Dent Endod 2024;27:730-6.

of endodontically treated teeth final restorations.[4,5] Pissi introduced ceramic crowns with a consistent core placed in the access cavity (Endocrown) as a substitute for post-and-core crown treatment in 1995, benefitting from tooth structure preservation and adhesive dentistry.[6] Endocrown restoration[7,8] is an alternative treatment option, in which a single unit system is placed in an root canal-treated tooth and attached to the inner part of the pulp chamber and to the cavity edges causing macromechanical and micromechanical retention.[9] Bindl and Mörmann improved the endocrown technique in 1999. After monitoring the patients for 2 years, they assured that the endocrown concept seemed clinically viable.[10]

In a detailed study by Sedrez-Porto *et al*.,[11] it was seen that endocrowns may perform similarly or better than traditional treatments such as postsupported crowns, direct composite restorations, inlays, and onlays. An exhaustive study by Govare and Contrepois[12] supported endocrowns as a dependable substitute for postretained restorations in molars and was suggested that more clinical research should be undertaken on the practice of endocrowns on premolars. Bindl *et al*.[10,13] questioned the application of endocrowns for premolars due to the pulp chamber space's smaller dimensions, which diminish bonding surface area. The addition of ferrule into preparations has been extensively studied for its improved fracture resistance.[14,15] The use of 0.5 mm ferrule has been shown to notably enhance fatigue cycles and cause failure in teeth treated with all ceramic crowns supported by post and core.[16] Due to the scarcity of information, the purpose of this study was to assess and evaluate the success rates of endocrown restorations on maxillary premolars in permanent teeth with and without ferrule designs.

Aims and objectives

The aim of our study was to check whether the incorporation of the ferrule in premolar endocrown design will alter its fracture resistance or not. The objective of our study was to compare fracture resistance of maxillary premolars endocrown due to the incorporation of ferrule in their design.

MATERIALS AND METHODS

The study was carried out to determine any alteration of fracture resistance of maxillary premolar endocrowns due incorporation of ferrule in its design.

A. Selection of samples: Inclusion criteria: Maxillary premolars which were extracted due to periodontal mobility and orthodontic extraction were selected. Exclusion criteria: Teeth with caries, fractures, curved canals, and immature apices were excluded
B. Preparation of samples: The sample consisted of 40 maxillary first premolars without cracks or caries extracted for orthodontic purposes or periodontal purposes. The teeth selected were of the same sizes and shapes by calculating the root length and buccolingual-mesiodistal widths at the cementoenamel junction (CEJ) by visual inspection and digital caliper measurements, encouraging a maximum deviation of 10% from the mean width which was buccolingual: 8.46 ± 0.4 mm and mesiodistal: 4.96 ± 0.4 mm
C. Teeth sample sterilization and storage: Teeth were sterilized by absorption in 5% sodium hypochlorite for 15 min at room temperature. All teeth were cleaned with ultrasonic scaler with low power under vigorous water and finally kept in saline solution at room temperature

   Before starting the procedure, the teeth were individually fixed with cold-cure acrylic resin. The crown structures of the teeth were kept free from the acrylic, and the root was covered by up to 2 mm beneath the CEJ, which was approximately the level of the alveolar bone in a healthy tooth
D. Removal of the coronal section of the tooth: The coronal portion of the teeth was sectioned above the CEJ up to 2 mm with the use of a super coarse diamond disc
E. Endodontic treatment: K-file (#10) was adopted to check the patency of the root canals, the working length was placed 1 mm short of the apex. Complete endodontic treatment using nickel–titanium files (ProTaper Gold-Dentsply Maillefer, Switzerland) SI, S2, F1 with a speed of 250 rpm was performed. After each filing was done, the canal was irrigated with sodium hypochlorite (5.25% w/v), dried with paper points, and obturated using a matched gutta-percha cone by lateral compaction technique. Euogenol-free resin sealer AH Plus (Dentsply Maillefer, Switzerland) was used. The excess gutta-percha was detached by a heated instrument (cherry red) followed by a periapical radiograph after obturation. Subsequently, teeth were assigned randomly in two groups (n = 20 each group):
   - Group A: Bulk-fill composite endocrown without ferrule
   - Group B: Bulk fill composite endocrown with ferrule.
F. Preparation of endocrown: An endocrown former was prepared previously with a rubber base condensation silicon putty impression material. Endocrowns were then prepared using the endocrown former with a dual-cure composite core build-up material (Core X Flow by Dentsply Maillefer) so morphologically they all were identical. The teeth were then prepared to receive endocrowns. A round inlay cavity extending 3 mm was adapted with a cylindrical bur, and the internal line angles were later rounded with a cylindrical diamond bur [Figure 1].

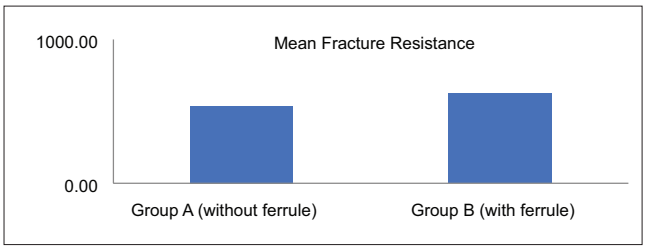
In the second group, we have constructed a ferrule of height 1.5 mm as well as a chamfer margin along the circumference of the tooth. After etching, the prepared tooth surface of all endocrowns was then bonded with dual-cure resin cement. After the light cure and final setting of the cement, the excess cement was trimmed and polished for fracture resistance testing.

The samples were then kept in a 30° inclined carrier which was prefabricated in the laboratory and then placed universal testing machine. Fracture resistance was noted in Newton, and failure modes of all samples were determined from visual and periapical radiographs after fracture.

1. "Unfavorable failures" were classified as nonrepairable, catastrophic failures below the CEJ and were termed as vertical root fractures
2. "Favorable failures," on the other hand, were defined as repairable failures above the CEJ and incorporated under adhesive failures. The values were obtained, and the fracture modes were acclaimed.

RESULTS AND OBSERVATIONS

In this study, fracture resistance of endocrowns with and without ferrule was compared and evaluated. The samples were divided into two groups: Group A (without ferrule) and Group B (with ferrule). The fracture resistance was tested for both the groups with the help of a universal testing machine. The data were tabulated in Microsoft Excel and analyzed with SPSS version 24 software [Tables 1-5]. The variables were presented with mean, standard deviation, and independent *t*-test. The $P \leq 0.05$ is considered statistically significant. The fracture resistance analyzed for two groups was as follows:



Bar graph shows the comparison of fracture resistance between Group A and Group B. Group B (with ferrule) showed higher fracture resistance (622.06 N) than Group A (537.59 N) (without ferrule). Independent *t*-test showed that the difference was statistically significant ($P = 0.008$).

DISCUSSION

The use of computer-aided-design/computer-aided-manufacturing (CAD/CAM) may be considered an effective method for restoring endodontically treated teeth, particularly when there is insufficient ferrule.[6,10,17] Studies showed that endocrown yields lower internal forces than full coverage restorations done through posts and cores.[18,19] Few studies suggest that endocrowns should only be used in molars.[13] The purpose of this study was to determine the significance of ferrule on premolar endocrowns on the basis of failure strength.

A survey conducted by Michael Einhorn *et al*.[12] confirmed that the accessible area for attachment was boosted by over 47% from the regular endocrown to the endocrown with a 2 mm ferrule; no difference in fracture strength was observed; however, a few results revealed that the ferrule groups failed considerably at higher loads than the normal endocrown restoration. In our analysis, we considered the failure load, and as a result, the ferrule group fared better. Failures that appeared to have adhesive damage could be repaired visually and were discovered to have irreparable fractures that, depending on location, may or may not be seen on a typical periapical film. However, because of limited resources, we simply tested for fracture failures using the dental operating microscope. Catastrophic failures were defined as tooth surface fractures including the preparation, whereas cohesive root fractures occurred apically and were not included in the preparation.

In standard endocrown fabrication, the findings of the investigation were similar to those of Biacchi and Basting,[17] who observed that failures of most endocrown occurred at a mean value of 674 N. Studies by El-Damanhoury *et al*.[20] showed that lithium disilicate demonstrated a mean fracture load of 1368 N. Gresnigt *et al*.[21] observed failure values higher than those seen in Michael Einhorn *et al.*'s study.[12] Those findings differ slightly from our current study due to the use of different force vectors, as well as endocrown material differences, as we have employed bulk-fill composite as our endocrown material. The conclusion by Micheal Enhorn *et al*.[12] supports a relatively recent report by Shin *et al*.[22] It is assumed that the inclusion of ferule would cause enough dentin loss from the endocrown preparation to diminish the overall complex. Hence, when a endocrown is selected in the preendodontic scenario, a more conservative access is recommended. Many clinical reports revealed the capacity of this restorative technique to offer appropriate purpose and esthetics, with impaired tooth integrity in devitalized premolars.[23] Hence, El-Hefnawy *et al*. conducted an *in vitro* investigation to evaluate the fracture resistance of PEEK endocrowns with that of postretained PPEK crowns with two different arrangement designs, with ferrule and without ferrule. PEEK material was selected for the investigation primarily due to its low modulus of elasticity, which is analogous to that of dentin, and its capacity to be sandblasted to form a strong and stable resin bond. In our study, human real teeth (maxillary first premolars) were used in an endeavor to accurately simulate the clinical condition in terms of tooth characteristics and anatomy.[24] The size of the chosen

teeth was standardized to reduce the potential differences and inaccuracies linked with natural human teeth in *in vitro* study.[23] PEEK does not satisfy esthetic requirements.[25] Thus, the application of a veneering substance affects the material opacity and shade. In contrast to their work, we have employed bulk-fill dual-cure flowable composite material, which allowed easy shade matching and final cementation.

The endocrowns were adjusted before luting to a length of 4 mm in the inner part of the pulp chamber to increase the surface area of cementation and retention of the restoration, thus preventing dislodgment from the root cavity under lateral forces.[25] Dual-cure resin cement (Calibra by Dentsply) was used for its cementation. This cement was chosen because it can be set on demand, is impervious to microleakage, and has lesser desiccation and hydration issues. El-Hefnawy *et al*., in his study,[24] regarding mandibular premolars acknowledged that postcore with 2 mm ferrule and CAD-CAM crown had much soaring mean fracture resistance than endocrown. This could be owing to the lessened surface area of adhesion of the endocrown in comparison to postcore, which had a much greater contact area for adhesion connecting the post and the 2 mm ferrule that supports the crown.[26-28]

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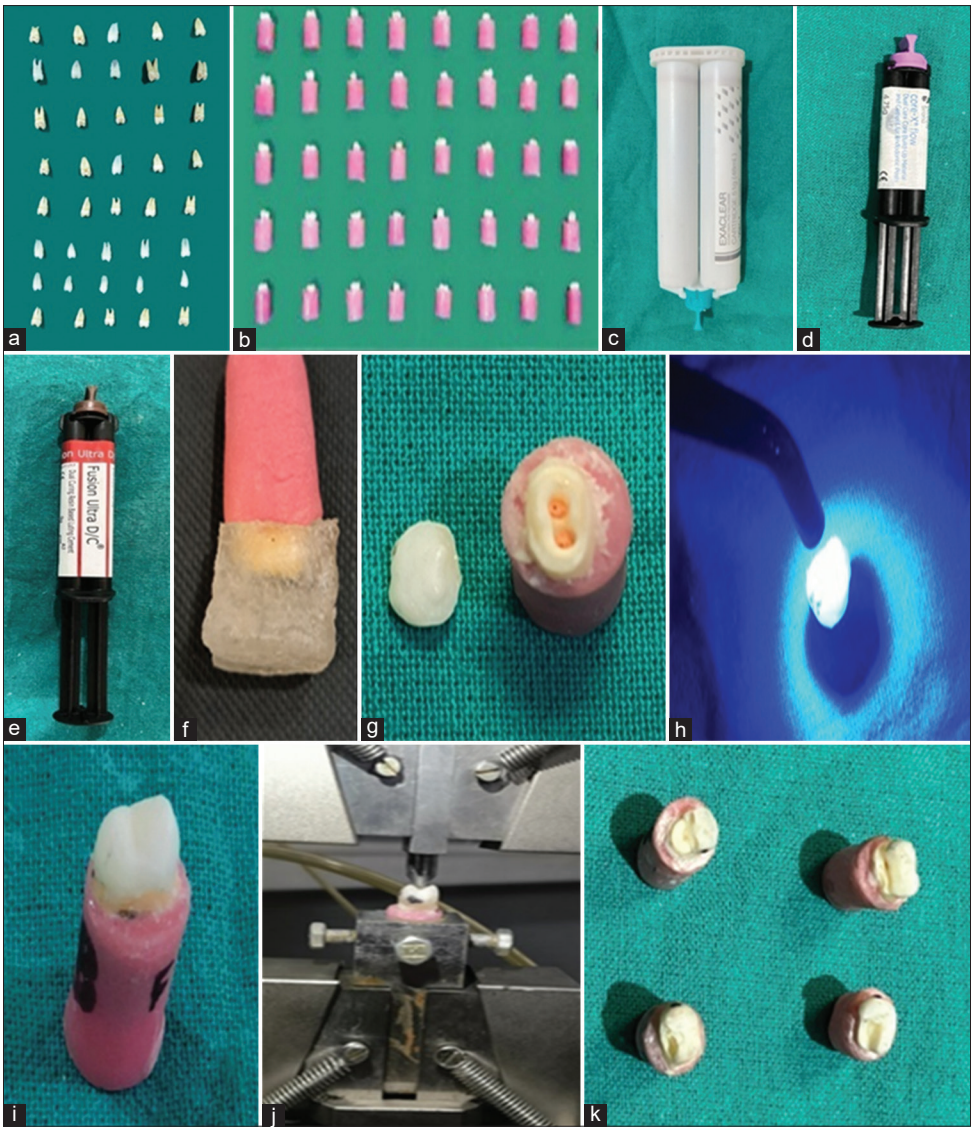

Figure 1: (a) Maxillary premolars, (b) Tooth embedded in acrylic resin, (c)-GC Exaclear polyvinyl siloxane material, (d) Core X Flow dual cure bulk fill composite resin, (e) Fusion ultra dual cure resin cement, (f) Impression recorded for endocrown, (g) Endocrowns after fabrication and ferrule placement, (h) Luting of endocrowns, (i) Endocrowns after luting, (j) Samples loaded in universal testing machine, (k) Catastrophic fractures recorded

Table 1: Distribution of fracture resistance in Group A (without ferrule)

Fracture resistance in Group A (without ferrule)
684.70
450.00
464.71
686.07
450.90
465.64
687.44
451.80
466.57
688.82
452.71
467.50
686.75
451.35
466.10
684.69
449.99
464.70
682.64
448.64

Table 2: Descriptive statistics of fracture resistance in Group A (without ferrule)

Group	Minimum	Maximum	Mean±SD
Group A (without ferrule)	448.64	688.82	537.59±103.8

SD: Standard deviation

Table 3: Distribution of fracture resistance in Group B (with ferrule)

Fracture resistance in Group B (with ferrule)
673.75
668.20
504.00
675.10
669.54
505.01
676.45
670.88
506.02
677.80
672.22
507.03
675.77
670.20
505.51
673.74
668.19
503.99
671.72
666.19

area for adhesion connecting the post and the 2 mm ferrule that supports the crown.[26-28] We did not compare endocrown with postcore crown design; instead, we tested endocrown with ferrule and without ferrule design, and our endocrown had adequate fracture resistance for maxillary first premolars. Endocrowns retention and stability require sufficient bonding. Another study found no significant difference between endocrowns and standard crowns, with post-core retention. Endocrowns reported identical stress levels as they incorporate both post and cores, which work as a single unit.[29] Lise *et al*.[30] investigated the influence of CAD/CAM material on the load-to-failure of nonvital premolars and discovered that resin composite seemed to be more superior than the lithium – disilcate glass-ceramic material.

Münchow *et al*.[31] created four groups employing resin-infused materials: Traditional resin composite mixed or not with resin adhesives as the modeler liquid and bulk-fill composite. Sedrez-Porto *et al*.[32] discovered that using resin adhesives as the modeler liquid in resin composites increased cohesiveness inside the bulk of the material, reducing hydrolysis after 6 months of storage. Teeth rebuilt with modeler liquid (Z350 + SBMP or Z350 + SBU) had a higher tendency to bear stress (i.e., larger deflection) according to their findings. It is worth mentioning that endocrowns arranged with resin adhesives did not have the highest load-to-fracture. In their study, however, they did reveal a different pattern of fracture, with the occurrence of less aggressive failure modes (mostly Type 1). The existence of resin adhesives inside the bulk of endocrowns has reduced the incidence of defect, hence improving the restorative systems' cohesion and resilience to affront during fatigue testing. To the best of our ability, this is an original study to construct endocrowns with a flowable dual-cure bulk-fill composite resin. Due to the material's flowability, we were able to prepare the endocrown efficiently without voids though the endocrowns made with the bulk-fill composite had the highest load to fracture mean values of the study (2681.4 N) according to the studies by Sedrez-Porto *et al*.[32]

Nonetheless, bulk-fill composites may create less polymerization stress than standard endocrowns,[33-35] positively influencing repair fatigue resistance and demonstrating their potential for the reconstruction of severely injured nonvital teeth. Few groups broke down at the tooth-restoration border (Type II failure mode), implying that failure took place due to a bonding rather than feebleness of the material involved in the fabrication of the endocrown. In our study, we have applied load at a 30° angle to the crowns, because lateral forces are more sensitive in the maxillary first premolar region than axial compressive pressures. In a recent study,[36] it was discovered that the use of self-adhesive resin cement could be used as a feasible option for dental cementation, ensuring high and allowable survival rates. The presence of Type 2 failures in the Sedrez-Porto *et al*.'s[11] study could be explained by the fact that the luting process affects the success of the restoration. A repairable fracture is always than an aggressive irreparable fracture. Fractures that extend to the root are often arduous to restore as surgical treatments may be required, lengthening the time and increasing the complexity and cost to the patient.[37]

Table 4: Descriptive statistics of fracture resistance in Group B (with ferrule)

Group	Minimum	Maximum	Mean±SD
Group B (with ferrule)	503.99	677.8	622.06±70.08

SD: Standard deviation

Table 5: Comparison of fracture resistance between Group A and Group B

Group	Mean±SD	*P*
Group A (without ferrule)	537.59±103.8	0.008
Group B (with ferrule)	622.06±70.08	

SD: Standard deviation

In our investigation, all groups showed relatively few catastrophic fractures as well. Eventually, it is important noting that the current discovery of our research may not be applicable right away to the clinic due to experimental circumstances that were fixed at 30° angulated loading. In the study by Gresnigt *et al*.[21] discovered that the axial loading forces constitute greater forces than lateral loading, which is mostly higher than the average masticatory forces in humans (600–900 N for females and males, respectively), overestimating the restorations's load-to-fracture performance.[38,39] In our study, we have tested the endocrowns under 30° angulated loading. Recently, meta-analysis and a detailed review were performed by Thomas *et al*.[40] for endocrown restorations for permanent molars and premolars. Their findings revealed equal benefit and no change in the rate of endocrown breakdown between molars and premolars, indicating that premolars may be suitable candidates for endocrown restorations. In our study, results also showing that endocrown are suitable postendodontic restorations as well and incorporation of the ferrule in design will improve its fracture resistance.

CONCLUSION

Within the limitations of this study, detected failure forces based on the accessible surface area for adhesive bonding showed no change in failure between typical endocrown preparations and those with 2 mm of ferrule. In comparison to failure load findings, it could be informed that ferrule-containing endocrown greater failure loads than ordinary endocrown restorations. In spite of the presence of a ferrule, this study revealed that endocrown restorations saw few catastrophic failures, but at forces higher than recorded normal masticatory performance. Based on these findings, fatigue studies can be considered to be pursued further.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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