Comparative Study on Fracture Resistance of Endodontically Treated Tooth in Relation to Variable Ferrule Heights Using Custom-made and Prefabricated Post and Core: An In Vitro Study

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Introduction: Endodontically treated teeth have significantly different physical properties compared to vital teeth. To ensure functional longevity, endodontically treated teeth must have at least 5 mm of tooth structure coronal to the crestal bone, 2 mm of coronal tooth structure incisal to the preparation finish line are necessary to ensure functional integrity. Aim and Objectives: To evaluate fracture resistance of endodontically treated teeth restored with custom cast post, custom cast post with variable ferrule height and teeth without ferrule, prefabricated post with variable ferrule height and teeth without ferrule. To compare fracture resistance of teeth restored with custom cast post and prefabricated post with variable ferrule heights. Materials and Methods: Methodology includes selection of teeth, root canal preparation, post space preparation, grouping of samples, Group A—custom cast post and core with sub groups of variable ferrule height, pattern fabrication, Group A - pattern fabrication for customized cast post. Group B—pattern fabrication for prefabricated post and core, investing and casting, cementation, custom made acrylic jig preparation, testing of specimens. Results: The difference in the fracture load between the samples of Group A was highly significant at the 0.001 level. Subgroup A4 had highest fracture resistance while Group A, possessed the least fracture resistance. Subgroups A2, A3 had fracture resistance value intermediate between A1, A4. Conclusion: Increasing the ferrule height significantly increases (P < 0.001) the fracture resistance of endodontically treated teeth restored with both custom made cast post and core and prefabricated post with metal core. Comparatively the custom made cast post and core with variable ferrule height, especially 2 mm ferrule showed significant fracture resistance than prefabricated post with metal core. The presence of 2 mm ferrule height significantly increases (P < 0.001).

Keywords: Custom-made cast post, custom-made jig, endodontically treated teeth, ferrule, prefabricated cast post

INTRODUCTION

The success achieved with aesthetic restoration has resulted in increased patient demands for these treatments. Consequently, there has been a significant increase in the use of all ceramic crowns and...
endodontic post with core.[1] Endodontically treated teeth need to be protected, because there is a risk of fracture, particularly in the cervical region, which is.[2] Endodontically treated teeth have significantly different strength compared to vital teeth.[3] To ensure the functional longevity, endodontically treated teeth must have at least 5 mm of tooth structure coronal to crestal bone, 3 mm needed to maintain a healthy soft tissue complex, and 2 mm of coronal tooth structure incisal to the preparation finish line are necessary to ensure the functional integrity.[4] It is generally accepted that restorative strategy to include to design a ferrule in tooth preparation when restoring endodontically treated tooth with a post and core and then restoring with crown. It has been stated that ferrule design improves the resistance to dynamic occlusal loading, maintains the integrity of the artificial crown retainer, and reduces the potential of concentration of stress at the junction of post with core. Furthermore, the ferrule effect reduces the wedging of tapered posts or bending forces during post insertion and helps to improve the marginal integrity of the fixed partial dentures.[5] The effectiveness of ferrule has been evaluated by a variety of methods, including fracture testing, fatigue testing, and photoelastic analysis.[6-10] Hence, it is decided to conduct a study on different ferrule heights ranging from 0, 1, 1.5, and 2 mm in a natural tooth as an in vitro study with the following aims, to evaluate the fracture resistance of endodontically treated teeth restored with custom-made cast post and prefabricated post with variable ferrule heights.

**Materials and Methods**

This study was performed to evaluate the influence of variable ferrule height fracture resistance of endodontically treated teeth restored with custom-made cast post and prefabricated post with core. Methodology includes, selection of teeth, root canal...
preparation, and post space preparation. Samples are grouped accordingly as follows: Group A—custom-made cast post and core with subgroups of variable ferrule height [Figure 1A–E] (A1 = 0 mm, A2 = 1 mm, A3 = 1.5 mm, and A4 = 2 mm) and Group B—prefabricated post with core, subgroups are named as follows; variable ferrule height (B1 = 0 mm, B2 = 1 mm, B3 = 1.5 mm, and B4 = 2 mm). Group B, pattern fabrication for prefabricated post and core, investing and casting, cementation, acrylic block preparation, preparation of metal core for receiving porcelain fused metal crown, custom-made acrylic jig preparation.

After post space preparation, 40 teeth were grouped into two major groups of custom-made cast post with core (Group A) and prefabricated post with metal core (Group B) [Figure 2]. Both Groups A and B are further divided into four subgroups with variable ferrule height.

For subgroups A1 and B1 [Figure 3A] (0 mm/no ferrule), the coronal aspects of the teeth were removed at the cementoenamel junction perpendicular to the long axis of the tooth by using high-speed handpiece with flat end tapering diamond. No coronal dentin was remaining.

For the subgroups [Figure 3B] A2 and B2 (1 mm), coronal tooth structure was reduced to a flat plane at a height of 1 mm coronal to cementoenamel junction circumferentially. Ferrule height was standardized by customized probe having measurement of 0.5, 1.0, 1.5, and 2.0 mm.

For the subgroups A3 and B3 (1.5 mm), the coronal tooth structure was reduced to a flat plane at a height of 1.5 mm coronal to cementoenamel junction circumferentially, the ferrule height was standardized by customized probe having the measurement of 0.5, 1.0, 1.5, and 2.0 mm. For the subgroups A4 and B4 [Figure 3D] (2 mm), coronal tooth structure was reduced to a flat plane at a height of 2 mm coronal to cementoenamel junction circumferentially, ferrule height was standardized by customized probe having the measurement of 0.5, 1.0, 1.5, and 2.0 mm. Custom-made acrylic jig preparation is shown in Figure 4. A custom-made jig, which would fit exactly in retaining the arm of universal testing machine, was made from the rectangular block of acrylic. This was designed to hold the samples at 135° to the proposed loading. It was to orient all the specimens in the universal testing machine at 135° angulation.

Testing of specimens

Each specimen was placed in custom-made apparatus that allowed the specimens to be positioned at 45° to the buccal/lingual axis. Specimens were subjected to loading at this orientation in a universal testing machine. The load was measured in Newton (N). Each specimen was embedded in a self-cured acrylic resin block from 2.0 mm apical to the margins of a porcelain-fused metal crown, and then loaded at 135° from the long axis in a universal testing machine at a crosshead speed of 1.0 mm/min until fracture. Static loading tests were performed on each specimen until failure (crack without a complete fracture).
RESULTS

This study was conducted to evaluate the fracture resistance of endodontically treated teeth restored with prefabricated post and custom-made cast post with variable ferrule heights. A total number of 40 samples were made. The samples were divided into two main Groups of A and B. These groups were further divided into eight subgroups of A1, A2, A3, and A4 and B1, B2, B3, and B4 of five samples each. All the samples were subjected to fracture test at particular load with universal testing machine. The load was recorded in Newton (N). The basic data of the results of this study are shown in Tables 1 and 2. The fracture loads of custom-made cast post with core (Group A) are given in Table 1. Fracture resistance of subgroup A4 is the highest (2 mm ferrule). Subgroup A1 (0 mm ferrule) has the least fracture resistance, with A2 and A3 in between these two. The fracture loads of prefabricated (Group B) post and core are given in Table 1. Subgroup B1 show a lowest fracture resistance. Remaining subgroups (B1, B2, and B3) for fracture loads are in increasing order. Subgroup B4 has the highest fracture resistant, Table 1 represents the mean fracture load of both groups A and B. The fracture load of Group A and Group B samples is subjected to the following test for statistical analysis.

One-way analysis of variance (ANOVA): when the mean values of three or more independent groups have to be compared, then one-way ANOVA test is used for observations. In the one-way ANOVA, the observed variability is subdivided into two components: Variability of the observations within a group about the group mean and variability of group mean between groups about overall mean. In this study, one-way ANOVA was used to determine the statistical differences in the fracture load between the groups.

Tukey honestly significant difference (HSD) test: a statistically significant one-way ANOVA only indicates that the population mean values are probably unequal. It does not pinpoint where the differences are, so to determine this, multiple comparison tests are carried out. In this study, significant difference was determined using ANOVA; the results of one-way ANOVA and Tukey HSD test are given in Table 1. Tukey grouping is given in alphabets. Groups arranged in alphabetical order denote decrease in fracture load, which is significant at 5% level [Table 1]. The difference in the fracture load between the samples of Group A was highly statistically significant at level of 0.001. Subgroup A4 had the highest fracture resistance, whereas subgroup A1 possessed the least fracture resistance. Subgroups A2 and A3 had fracture resistance values close to each other. Differences were significant at a significant level of 0.050 [Table 2]. The differences in fracture load between Group A and Group B were compared by paired Student’s t test and was highly significant at the level of 0.001%. Subgroup B4 had the highest fracture resistance, whereas subgroup B1 possessed the least fracture resistance values. The subgroups B2 and B4 have fracture resistance value intermediate between B1 and B4. The differences were significant at a significant level of 0.001% [Table 2].

| Subgroup | Fracture load of Group A | P value | Fracture load of Group B | P value |
|----------|--------------------------|---------|--------------------------|---------|
| Mean     | SD                       |         | Mean                     | SD      |
| 1        | 728.08                   | 25.84   | <0.001**                 | 558.64  | 12.99   | <0.001** |
| 2        | 760.06                   | 18.49   | 635.12                   | 16.66   |
| 3        | 812.70                   | 44.49   | 725.78                   | 15.50   |
| 4        | 838.46                   | 32.61   | 755.76                   | 11.26   |

SD = standard deviation

**Differences are statistically significant at the 0.001 level.

| Subgroup | Fracture load of Group A | Fracture load of Group B | P value |
|----------|--------------------------|--------------------------|---------|
| Mean     | SD                       | Mean                     | SD      |
| 1        | 728.08                   | 558.64                   | 12.99   | <0.001** |
| 2        | 760.06                   | 635.12                   | 16.66   | <0.001** |
| 3        | 812.70                   | 725.78                   | 15.50   | <0.003** |
| 4        | 838.46                   | 755.76                   | 11.26   | <0.003** |

SD = standard deviation

**Differences are statistically significant at the 0.001 level.
with respect to preservation and fracture strength of as strength and modulus of elasticity, are important and certain physical characteristics of materials, such performance of the post, the dimension of the post force was between 343 and 362.6 N. In this study, this force increased to 254.8 N and the maximum 215 N. In the presence of para-functional loading, that the mean force applied on a maxillary canine was end on sound tooth structure, and avoid invasion of the have parallel dentinal walls, totally encircle the tooth, effect it should be a minimum of 1.5 mm in height and suggested that to achieve the full benefits of ferrule showed that 1 mm of remaining coronal tooth structure nearly doubled the fracture resistance of tooth. The presence of remaining coronal tooth structure was able to resist compressive load, surface hardness, and wear resistance. Shillingburg et al. found when all tooth structures have been lost to the level of alveolar crest or beyond, because of either fracture or caries, the tooth cannot be satisfactorily restored without some extraordinary measure; even if a dowel core placed in tooth, root will remain susceptible to fracture unless the crown encircles the tooth apical to the core. The ferrule effect around the tooth protects it from fracture by dowel from within, in fact if tooth structure is lost “only” to the level of epithelial attachment, it may be desirable to permit access to enough tooth structure apical to the finish line to produce a ferrule effect. This study also confirms that the presence of ferrule of 1.5 mm and 2 mm reduces significantly fracture of root (P < 0.001). Tan et al. observed that tooth with a nonuniform ferrule is more effective at resisting fracture than a tooth with no ferrule but not as effective as a tooth with a uniform 2 mm ferrule. The result of this study is in agreement with that of Tan et al. Pareira et al. showed that most common cause of failure when using a direct technique (prefabricated post with composite resin) fractured the restorative material, and when the cast post with core was used, the most common failure was the fracture of root. In this study, prefabricated post with metal core that covers the ferrule, commonly fractures at junction between cementoenamel junction and remaining coronal tooth structure. This investigation showed that roots restored by custom-made cast posts showed higher fracture force resistance than those restored by prefabricated post with metal core. Despite its lower resistance, the prefabricated posts may be appropriate because there were no root fractures. Thus, this study showed that increase in ferrule height increases fracture resistance of teeth samples restored with both custom-made cast post and prefabricated post with metal core and maximum fracture resistance attained at a ferrule height of 2 mm. The custom-made cast post showed more resistance against the fracture when compared to prefabricated post and core. From the results of this study, it is observed that the custom-made cast
post showed more resistance against the fracture even though the fracture was noticed at root level in some samples. The prefabricated post though needs lesser force to fracture, the occurrence of root fracture is comparatively less. As this study was conducted as an in vitro study, it has got its own pitfalls, such as dry atmosphere and fatigue loading. Further modified studies may be helpful to assess more details about the ferrule effect.

**CONCLUSION**

Within the limitation of this study, it can be concluded that increasing ferrule height significantly increases ($P < 0.001$) the fracture resistance of endodontically treated teeth restored with both custom-made cast post and core and prefabricated post with metal core. Comparatively, the custom-made cast post and core with variable ferrule height, especially 2 mm ferrule height, was statistically significant ($P <0.001$) to the fracture resistance of endodontically treated teeth restored with both custom-made cast post with core and prefabricated post with metal core when compared with teeth without ferrule.

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**Conflicts of interest**

There are no conflicts of interest.

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