ORIGINAL RESEARCH

A Comparative Study on Stress Distribution of Cast Metal and Zirconia Post and Core with Different Ferrule Height on a Mandibular First Molar with Metal Ceramic Crown – A Three-dimensional Finite Element Analysis

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ABSTRACT

Introduction: A cast post and core is a custom-made one-piece unit to stabilize a weakened tooth by resisting the lateral forces from the dowels, increasing the retention and resistance of the restoration. The ferrule is an encircling metal band around the root or coronal surface of a tooth. The pattern of stress distribution by the endodontic posts and the ferrule design under masticatory load is of great importance in ensuring an optimal design for prosthesis. Through finite element analysis (FEA), stress distribution on the endodontic posts and the ferrule design under masticatory load has been evaluated.

Aims: This study aims to compare the stress distribution in mandibular first molar with two different post materials restored with two different ferrule heights cemented with metal-ceramic crown.

Methods: The four models were created with varying ferrule designs and post materials and FEA done.

Results: In all the von Mises stress values, the maximum stresses were observed in the cervical area of crown, the cervical area of post and core interface or at the finish line of the tooth, and irrespective of ferrule height or post material and minimum stresses are observed in the apical area of the post or the root of the tooth. Lesser stresses are produced when the ferrule is incorporated, irrespective of material type.

Conclusion: Within the limitations of this study, custom-made zirconia post and core registered lower stresses than the Co-Cr cast post and core. Zirconia post has the least stress on higher ferrule height. Greater the modulus of elasticity of the material than dentine, lesser the force concentrated on the cervical area of the post and crown. Lesser stresses are produced when the ferrule is incorporated, irrespective of the type of material.

Keywords: Cast post and core, Cobalt-chromium, Endodontically treated tooth, Ferrule height, Finite element analysis, Mandibular first molar, Zirconia

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INTRODUCTION

Coronal tooth structure may be lost for a variety of reasons such as caries, previous restorative treatment, traumatic injury, attrition, erosion, abrasion, and resorption (internal and external). The extent of the destruction is an important determinant factor in deciding on the restorative techniques and materials to be used in restoring the tooth to normal form and function. The use of post and core is a recognized treatment modality to retain final restoration in an endodontically treated tooth when a large amount of coronal structure has been lost.[1] The selection of a particular type of endodontic post is based on its mechanical properties, ease of fabrication, biocompatibility, availability in the market, and the cost factor which is essential for the survival of a restoration[2] and for achieving long-term prognosis.[3] In cast post, the core retains well, has less vertical fracture during preparation, has high strength, preserves maximum tooth structure, and fits well.[4] One other important design consideration is the incorporation of the concept of "ferrule" or "the ferrule effect" that has been accepted as one of the foundations of the restoration of the endodontic-treated tooth.[5] It resists the lateral forces from the dowels or posts, resists the leverage from the crown in function, and also increases the retention and resistance of the restorations.[6] Some of the reasons for the failure of restorations for many years have been root fracture, microleakage, decementation, and metal corrosion in clinical practice.[7] Moreover, the concentration of forces affecting fracture of post-restoration during the functions of oral cavity.[8] The range of biting force varies markedly from one area of mouth to another and from one individual to another. An average load of 500 N was determined

for the study. Earlier stress distribution studies were done in metals such as titanium, nickel-chromium, stainless steel, and gold alloy restored with anteriors.[9-11] Here, metal cast post like Co-Cr alloy is selected due to its easy availability, low cost, biocompatibility, tarnish, and corrosion resistance.

Aim

This study aims to evaluate and compare the stress distribution in mandibular first molar under masticatory load restored with different post and core materials (Zr and Co-Cr) and with different ferrule heights (1 mm and 2 mm) cemented with metal ceramic crown.

METHODS OF STUDY

The cobalt-chromium cast post and core and custom-made zirconia post and core restored with 1 mm and 2 mm ferrule heights on a mandibular first molar, were modeled in Pro-E software, and created with real dimensions and features. Four groups were made. All the materials of the models were isotropic and homogenous.

- Group I – Custom-made zirconia post and core with 1 mm ferrule height restored with porcelain-fused metal (PFM) crown
- Group II – Custom-made Co-Cr post and core with 1 mm ferrule height restored with PFM crown
- Group III – Custom-made zirconia post and core with 2 mm ferrule height restored with PFM crown
- Group IV – Custom-made Co-Cr post and core with 2 mm ferrule height restored with PFM crown.

After producing the models, meshing was done; thereafter, they were transferred to the finite element program ANSYS Workbench software (Swanson Analysis Inc., Houston, PA, USA) Material properties were entered into the software and 500 N occlusal forces were applied in oblique and vertical directions. When the forces were applied on the models, there occurs a change in the shape of nodes and elements that determine the stress distribution.

RESULTS

Lesser forces on tooth observed in custom-made zirconia post and core with 2 mm ferrule height. In comparison

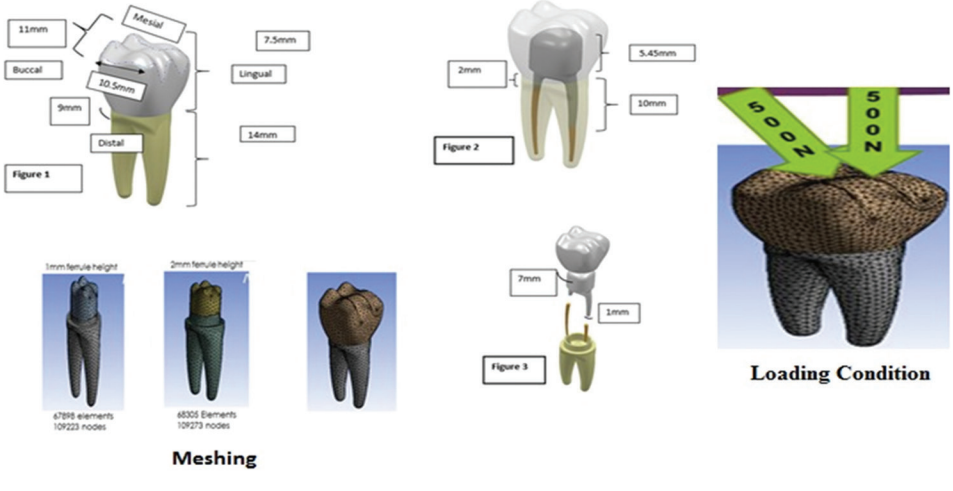
	Stress in post			
	Cobalt-chromium		Zirconia	
	Vertical	Oblique	Vertical	Oblique
1 mm ferrule	180	244.72	36	66
2 mm ferrule	45	82	30	60
	Stress in tooth			
1 mm ferrule	165	190	100	100
2 mm ferrule	120	100	70	80

with ferrule heights, 2 mm produced lesser stresses on tooth than 1 mm. In comparison to material, zirconia produced lesser stresses on tooth with 1 mm and 2 mm ferrule height than Co-Cr post and core with 1 mm and 2 mm ferrule height. In comparison with force, vertical force produced lesser stress on tooth than oblique force.

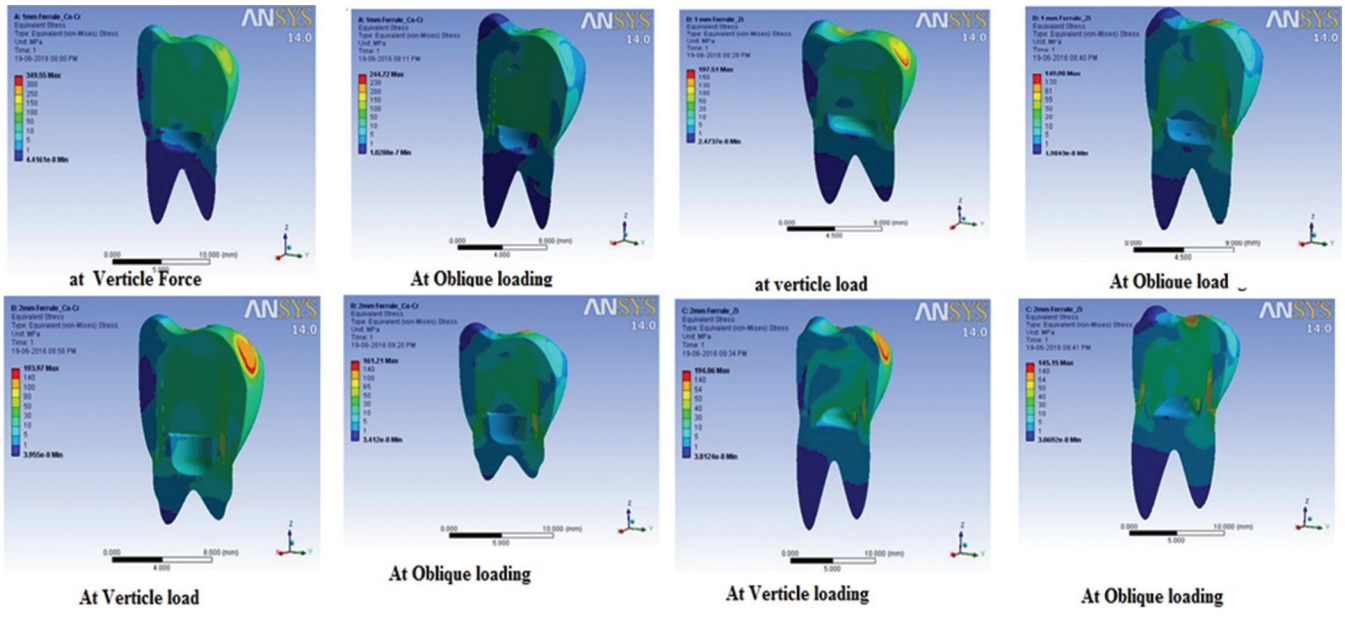
In all the von Mises stress values, the maximum stresses were observed in the cervical area of crown, the cervical area of post and core interface or at the finish line of the tooth, and irrespective of ferrule height or post material and minimum stresses are observed in the apical area of the post or the root of the tooth. Lesser stresses are produced when the ferrule is incorporated, irrespective of material type. In all the models, higher magnitude is produced in the buccal aspect of the crown.

DISCUSSION

The customized cast post and core possesses superior adaptation to the root canal, associated with little or no stress with installation, and high strength in comparison to the prefabricated post. Its recommended use is with elliptical or flared canals. The ability of post-core



system to sustain masticatory forces and remain firmly seated in the tooth is essential for the survival of a restoration.[2] Earlier stress distribution studies were done in metals such as titanium, nickel-chromium, stainless steel, and gold alloy restored with anteriors.[2,11] Metal cast post like cobalt-chromium alloy is selected for the study due to its easy availability, low cost, biocompatibility, tarnish and corrosion resistance, chemically inert, and greater stiffness and has not been studied yet. Here, mandibular first molar is selected because it is subjected to greater loading, occlusal forces than anterior teeth. Due to the change in the morphology, the cusps can be wedged apart that is, it is susceptible to fracture. Zirconia post is selected to compare and evaluate the stress distribution with cobalt-chromium post and to bring up with conclusions to apply in the clinical practice. Combined together, the pattern of stress distribution by these two endodontic posts with two different ferrule designs, i.e., 1 mm and 2 mm under masticatory load will ensure an optimal design for the prosthesis. Therefore, four models were created with real dimensions with varying ferrule heights, i.e., 1 mm and 2 mm each for cobalt-chromium cast post and core and custom-made zirconia post and core restored on a mandibular first molar cemented with metal-ceramic crown. Finite element analysis was done by applying force on the occlusal surface of the prosthetic crown, in angular direction (30°) and vertical direction with a magnitude of 500 N at the buccal cusp tips and lingual inclination of buccal cusp, respectively. Von Mises stress distribution values were taken and results were recorded. In comparison with ferrule heights, 2 mm produced lesser stresses on tooth than 1 mm. In comparison to material, zirconia produced lesser stresses on tooth with 1 mm and 2 mm ferrule height than Co-Cr post and core with 1 mm and 2 mm ferrule height. In comparison with force, vertical force produced lesser stress than oblique force. In all the von Mises stresses, the maximum stresses were observed in the cervical area of crown, the cervical area of post and core interface or at the finish line of the tooth, and irrespective of ferrule height or post material and minimum stresses are observed in the apical area of the post or the root of the tooth. Lesser stresses are produced when the ferrule is incorporated, irrespective of material type. In all the models, higher magnitude is produced in the buccal aspect of the crown. Many studies suggest that the greater the height of remaining tooth structure above the margin of the preparation, the better fracture resistance provided.[12-16] A ferrule of 2 mm of vertical height successfully doubled the resistance to fracture which is in line of this study. Many studies have been done on different materials of post and core systems. Some studies state that to achieve optimum results, the material used for the post should have physical properties similar to that of dentin, can be bonded to the tooth structure, and biocompatible in the oral environment. Adanir and Belli evaluated the effects of different post materials on the stress distribution in an endodontically treated maxillary incisor with five posts with different physical properties consisting of stainless steel, titanium, gold alloy, glass fiber (Snowpost), and carbon fiber (Composipost). It is found that, posts made of metallic posts showed greater stress concentration at the post-dentine interface than fiber posts. However, fiber posts produced the highest stress values at the level of one-third of the cervical area of the crown. They concluded that the physical characteristics of posts were important on stress distributions. Fiber post provides more sustained clinical service for patients. However, fiber posts are not an option, when there will be little or no ferrule, or when excessive occlusal forces are present.[17] There comes the relevance of this study, posterior teeth



tend to have excessive occlusal forces. Evidence regarding the most adequate type of post to restore pulpless teeth remains controversial and this issue is still a major concern in dentistry.[18] No universal recommendations have been established, however, many studies demonstrate that the presence of a ferrule of 1.5–2 mm sound coronal tooth structure between the core and the finish line is more important in fracture resistance than the post design or type.[18] This finite element method study revealed that the increase in the ferrule improved the mechanical resistance of a post/core/crown restoration in mandibular first molar. Therefore, the tooth should have a minimum amount of 2 mm of coronal structures above the cementoenamel junction to ensure proper strength and to prevent root fracture, post-fracture, and dislodgement. It prevents the wedge effect and improves the load distribution. Second, the study revealed that both Co-Cr cast post and core and custom-made zirconia post and core which have high modulus of elasticity greater than dentine lead to higher stress in the post which distributes less stress in tooth – post interface and cervical area of the crown. What seems clear is that the greater the height of remaining tooth structure above the margin of the preparation, the better fracture resistance provided. Moreover, lesser stress distribution on teeth observed.

CONCLUSION

The study revealed that both Co-Cr cast post and core and custom-made zirconia post and core which have high modulus of elasticity greater than dentine lead to higher stress in the post which distributes less stress in tooth – post interface and cervical area of the crown. In comparison between zirconia post and core and cobalt-chromium post and core, zirconia post and core has less modulus of elasticity than cobalt-chromium cast post and core. Therefore, lesser forces are produced by zirconia. Thus, null hypothesis is rejected. The limitation of the study is that it is a computerized *in vitro* study where clinical condition may not be able to precisely replicate the oral conditions. The following conclusions were drawn from this study.

- Custom-made zirconia post and core registered lower stresses than the Co-Cr cast post and core
- Zirconia post has the least stress on 2 mm ferrule height
- The post and core restored with 2 mm ferrule height showed a significant reduction in stresses on the tooth
- Greater the modulus of elasticity of the material than dentine, lesser the force concentrated on the cervical area of the post and crown
- Lesser stresses are produced when the ferrule is incorporated, irrespective of the type of material.

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