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Strength Estimation of Teeth Reinforced with Different Types of Post Systems

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Posts are permanent, single-tooth and periodontal restorations. During chewing, forces make teeth with posts to undergo complex stresses. The aim of this work is to compare and estimate the upper medial incisors restored with custom posts and prefabricated composite posts reinforced with fibreglass using the finite element method. Modelling and numerical analyses provide the opportunity to evaluate the reconstruction of teeth using custom and prefabricated posts.

Key words: finite element method, periodontium, prefabricated and custom post.

1. Introduction

Posts are permanent, single-tooth and periodontal restorations consisting of a crown segment which significantly reconstructs damaged tooth crowns and a root part located in root canal of an endodontically treated tooth (Fig. 1). Custom posts, made of metal alloys (chrome cobalt, gold, chrome-nickel or silver-palladium), have been used over the years. The development of modern material technology has enabled prefabricated posts to be produced. These restorations are made of metals (precious metal alloys, stainless steel, titanium and its alloys), ceramics (zirconium oxide) and a composite reinforced with fibreglass or carbon

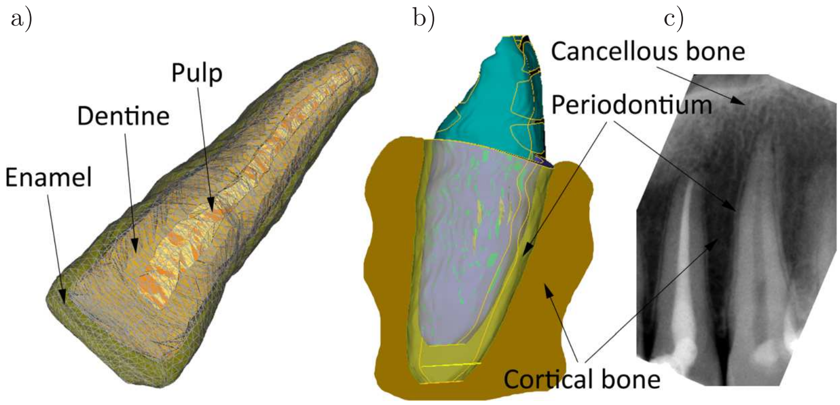

Fig. 1. Dental reconstruction: a) model of dental layers divided in tetrahedral elements, b) model of teeth with periodontal ligament, c) real radiography photo of a tooth and surrounding tissues.

fibre. In clinical practice, there is often a question of which post to choose [3, 7, 8, 15].

The aim of this work is to compare and estimate the upper medial incisors reconstructed with custom posts and prefabricated composite posts reinforced with fibreglass using the finite element method (FEM). The frequently encountered problem is to select the appropriate posts based on durability, adhesion method, and the principles of treating tooth tissues, the possibility of removing posts, aesthetics, biocompatibility, and clinical aspects of restoration sustainability in practice.

2. Materials and method

The materials of this study were two groups of numerical models of teeth. In the first group, the teeth were strengthened with custom posts and a prosthetic ceramic crown. In this group, the posts were made of metal – alloy CoCr and zirconia – ZrO_2 stabilized with yttrium. The second group included the teeth supported with standard composite posts with fibreglass and later restored with composite material and a ceramic crown. All the virtual models included the periodontium model (Figs. 2, 3).

During chewing, due to forces, a tooth with a crown-root post undergoes complex stresses. The vertical component (along the long axis) burdens the tooth causing compression. That is why, to prevent it from cracking, the surface of the contact is increased – a flat bearing surface is formed and the restoration is fixed with cement in the canal (Fig. 4).

The horizontal component of the chewing force makes both a tooth and a restoration to bend, and the labial root surface may be broken. Thus, a tooth

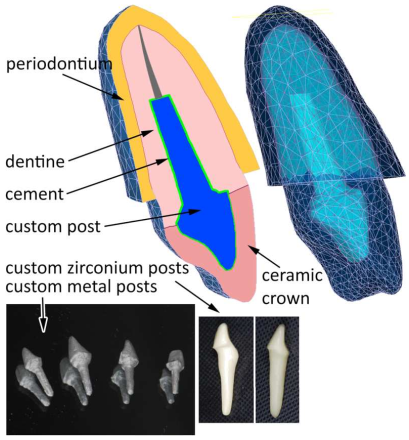

Fig. 2. Material of the tests – teeth strengthened with custom posts (CoCr, ZrO2) and prosthetic crown.

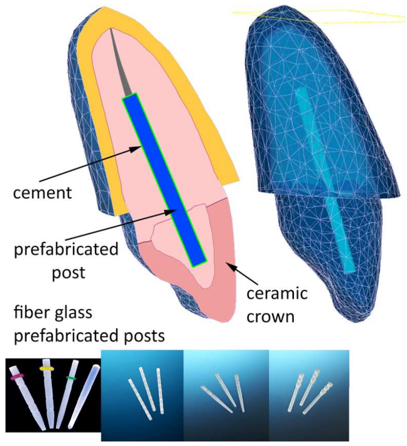

Fig. 3. Material of the tests –teeth strengthened with standard post (FCR) and the prosthetic crown.

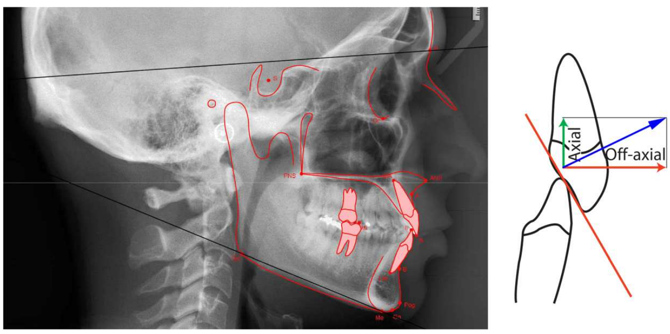

Fig. 4. Biomechanics of a tooth restored using the posts.

is burdened by the forces of torsion due to chewing. In the case of front teeth, the forces act from the lateral side on the incisal edge. The forces generate stress in teeth and surrounding tissues. The most significant use of a post is to provide uniform and safe distribution of stresses. A post must be strong enough to take all the stresses without the risk of causing strain on tissues. The models were fixed onto the periodontium. Stresses of 150 N were applied to the palatal surface with the help of vectors with directions resulting from the biomechanical analysis and twist to the surface of the tooth (Fig. 5).

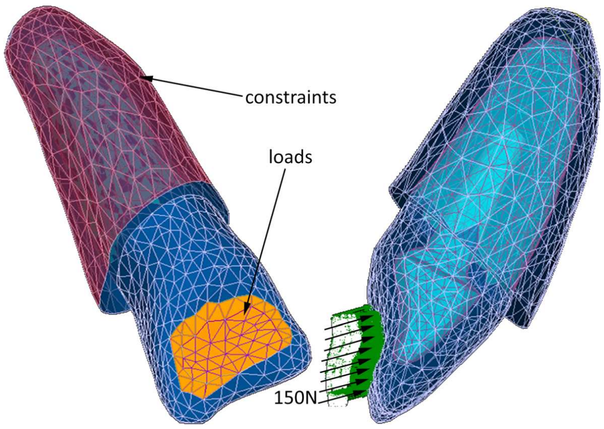

FIG. 5. The constraints (on the periodontal surface) and loads (on the occlusal surface) of virtual model.

Modelling and strength analysis were carried out using FEMAP NEi/Nastran v.8.3 (Table 1) [13–15]. To identify and estimate the stresses, the Huber-Misses-Hencky (HMH) hypothesis was used.

Table 1. Mechanical properties of tissues of stomatognathic system and the construction materials.

Material/Tissue	Young's modulus E [MPa]	Poisson's ratio ν
Cortical bone	14 700	0.30
Cancellous bone	490	0.30
Periodontium	50	0.45
Pulp	2.0–0.0003	0.45
Dentine	18 300	0.31
Enamel	84 100	0.30
Ceramics	96 000	0.19
Metal alloy	218 000	0.33
Zirconium	210 000	0.24
Fiberglass	40 000	0.41

3. Results of tests

The analysis shows that maps of the stress distributions in the structure of teeth restored with individual post systems made of metal and zirconium oxide are similar in nature (Figs. 6a,b and 7a,b). The zones of maximum stress of 5 MPa are present in both posts in the root portion and in the transition area in the root portion of the crown, while the stress distributions are more evenly balanced in the tooth restored with the zirconia post than with the metal post. In the crowns of both models, uniform stress distributions of 0 to 0.9 MPa were found in the lip portion (the front), and from 2 to 2.8 MPa in the area of gingival edge. Such a distribution of stresses may have a stabilizing effect on the contact of the crown with the restoration of the stromal root and its contact with the

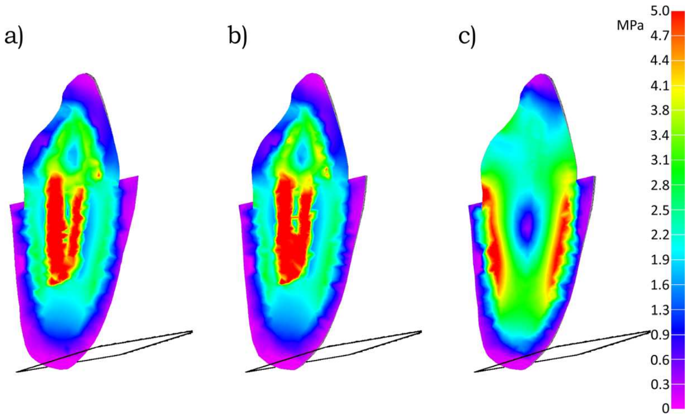

Fig. 6. The distributions of stresses in the sagittal section in teeth strengthened with posts: a) metal custom post (CoCr), b) zirconium custom post (ZrO_2), c) fibreglass standard post (FRC).

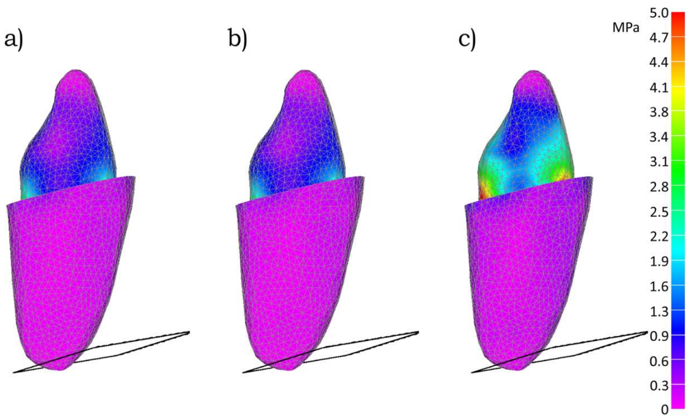

Fig. 7. The distributions of stresses in teeth strengthened with posts (the view with periodontium): a) metal custom post (CoCr), b) zirconium custom post (ZrO_2), c) fibreglass standard post (FRC).

chamfer [1]. In teeth restored with individual posts, the cushioning nature of the periodontium is visible.

In the model of the tooth restored using standard composite post systems with fibre-reinforced composite (FRC), the zone stress concentrations occur outside the post – in the dentine of the root and in the contact zone of the crown with the chamfer, especially in the palatal side exposed to bending (Fig. 6c, Fig. 7c). The stress accumulation value of 4–5 MPa occurring peripherally deteriorates the area of adhesive contact of the post with the tooth structure and the stabilisation of the crown. In this type of post, there is also a deterioration of damping by the periodontium.

The teeth rebuilt with metal and zirconium posts are more resistant to breakage of the posts than those built from composite material reinforced with fibreglass. That is why, FRC posts are contraindicated at significant occlusive burdens. Destructive force usually causes the damage of a less resistant dentine and not the post regardless of its type. Fractures of teeth with FRC usually occur in the neck of the tooth, in contrast with the poorly promising fractures of teeth with custom metal posts and zirconium ones (occurring inside the root).

4. Discussion

The clinical experiences and stress analyses show that each patient should be treated individually especially after endodontical treatment in which it is advisable to use the post and core systems [2, 20, 21]. The tooth location, the condition of the hard tissues, the strength of the occlusion forces acting on the tooth and the aesthetic requirements connected with the material of the crown or bridge, under which the post will be located, should be analysed. Fibreglass causes brightening of the root and the tooth, unlike the metal inserts, whose impermeability to light often shows up as blackout surrounding the tooth. The obtained distributions of stresses confirm the clinical observations of damage to teeth reinforced with various types of posts – for example, cervical fractures of teeth with FRC posts [6, 10, 17]. Furthermore, zirconia is the material which combines aesthetics and strength [4].

The original solution presented in this work is the addition of the periodontium in the research model. The amortization of displacements coming from occlusion forces occurs in the periodontium, and the stresses compressionally stimulate crestal bone in the physiological range.

The reports in the literature about the strength of teeth reinforced with post and core are consistent with the studies in [5, 11, 12, 15].

The indications for use of individual post systems are: the damage of the hard tooth tissues below the alveolar ridge, the change of the direction of the long axis of the tooth (indications due to prosthetic reasons, tooth outside the arch), inability to achieve the stabilization of the prefabricated post – wide or oval root canal [9, 16, 18, 19, 22].

5. Conclusions

The modelling and numerical analyses make it possible to evaluate the reconstruction of teeth using custom and prefabricated posts.

Crowns based on individual posts of metal and zirconium are more resistant to damage and are better sealed than crowns based on standard composite FRC posts.

The original solution presented in this work is taken into account in the research on the periodontal model. In the periodontium, the amortisation of the displacement originating from the forces of occlusion occurs, and compression stresses stimulate the alveolar ridge in the physiological range.

References

1. Borba M., Duan Y., Griggs J.A., Cesar P.F., Della Bona A., *Effect of ceramic infrastructure on the failure behavior and stress distribution of fixed partial dentures*, Dental Materials, **31**: 413–422, 2015, doi: 10.1016/j.dental.2015.01.008.
2. Chen A., Feng X., Zhang Y., Liu R., Shao L., *Finite element analysis of stress distribution in four different endodontic post systems in a model canine*, Bio-Medical Materials and Engineering, **26**(S1): S629–635, 2015, doi: 10.3233/BME-151354.
3. Chen A., Feng X., Zhang Y., Liu R., Shao L., *Finite element analysis to study the effects of using CAD/CAM glass-fiber post system in a severely damaged anterior tooth*, Bio-Medical Materials and Engineering, **26**(S1): S519–525, 2015, doi: 10.3233/BME-151341.
4. Chen D., Wang N., Gao Y., Shao L., Deng B., *A 3-dimensional finite element analysis of the restoration of the maxillary canine with a complex zirconia post system*, The Journal of Prosthetic Dentistry, **112**: 1406–1415, 2014, doi: 10.1016/j.prosdent.2014.05.017.
5. Cormier C.J., Burns D.R., Moon P., *In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration*, Journal of Prosthodontics, **10**(1): 26–36, 2001, doi: 10.1111/j.1532-849X.2001.00026.x.
6. da Silva N.R. *et al.*, *Effect of resin cement porosity on retention of glass-fiber posts to root dentin: an experimental and finite element analysis*, Brazilian Dental Journal, **26**(6): 630–636, 2015, doi: 10.1590/0103-6440201300589.
7. Dejak B., *The study of stresses in teeth rebuilt with crown-root inlays made of different materials* [in Polish], Stomatologia Współczesna, **1**: 35–40, 1995.
8. Durmuş G., Oyar P., *Effects of post core materials on stress distribution in the restoration of mandibular second premolars: a finite element analysis*, J. Prosthet. Dent., **112**(3): 547–554, 2014, doi: 10.1016/j.prosdent.2013.12.00.
9. Eraslan O., Aykent F., Yücel M.T., Akman S., *The finite element analysis of the effect of ferrule height on stress distribution at post-and-core-restored all-ceramic anterior crowns*, Clinical Oral Investigations, **13**(2): 223–227, 2009, doi: 10.1007/s00784-008-0217-5.

10. Ferrari M. *et al.*, *Long-term retrospective study of the clinical performance of fiberposts*, American Journal of Dentistry, **20**(5): 287–291, 2007.

11. Fokkinga W.A., Kreulen C.M., Vallittu P.K., *A structured analysis of in vitro failure loads and failure modes of fiber, metal, and ceramic post-and-core systems*, International Journal of Prosthodontics, **17**(4): 476–482, 2004.

12. Fredriksson M., Astbäck J., Pamenius M., Arvidson K., *A retrospective study of 236 patients with teeth restored by carbon fiber-reinforce depoxyresin posts*, Journal of Prosthetic Dentistry, **80**(2): 151–157, 1998.

13. González-Lluch C., Pérez-González A., *Analysis of the effect of design parameters and their interactions on the strength of dental restorations with endodontic posts, using finite element models and statistical analysis*, Computer Methods in Biomechanics and Biomedical Engineering, **19**(4): 1–12, 2015, doi: 10.1080/10255842.2015.1034116.

14. Kumar P., Rao R.N., *Three-dimensional finite element analysis of stress distribution in a tooth restored with metal and fiber posts of varying diameters: An in-vitro study*, Journal of Conservative Dentistry, **18**(2): 100–104, 2015, doi: 10.4103/0972-0707.153061.

15. Madfa A.A. *et al.*, *Stress distributions in maxillary central incisors restored with various types of post materials and designs*, Medical Engineering & Physics, **36**(7): 962–967, 2014, doi: 10.1016/j.medengphy.2014.03.018.

16. Naumann M., Sterzenbach G., Rosentritt M., Beuer F., Frankenberger R., *Is adhesive cementation of endodontic posts necessary?*, Journal of Endodontics, **34**(8): 1006–1010, 2008, doi: 10.1016/j.joen.2008.05.010.

17. Pegoretti A., Fambri L., Zappini G., Bianchetti M.F., *Finite element analysis of a glass fiber in forced composite endodontic post*, Biomaterials, **23**(13): 2667–2682, 2002, doi: 10.1016/S0142-9612(01)00407-0.

18. Santos-Filho P.C. *et al.*, *Influence of ferrule, post system, and length on stress distribution of weakened root-filled teeth*, Journal of Endodontics, **40**(11): 1874–1878, 2014, doi: 10.1016/j.joen.2014.07.015.

19. Santos-Filho P.C. *et al.*, *Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth*, Journal of Endodontics, **40**(1): 119–123, 2014, doi: 10.1016/j.joen.2013.09.034.

20. Schilling K.U. *et al.*, *The influence of the root cross-section on the stress distribution in teeth restored with a positive-locking post and core design: a finite element study*, Biomedical Engineering/Biomedizinische Technik, **53**(5): 255–258, 2008, doi: 10.1515/BMT.2008.037.

21. Singh S.V. *et al.*, *Stress distribution of endodontically treated teeth with titanium alloy post and carbon fiber post with different alveolar bone height: a three-dimensional finite element analysis*, European Journal of Dentistry, **9**(3): 428–432, 2015, doi: 10.4103/1305-7456.163228.

22. Upadhyaya V. *et al.*, *A finite element study of teeth restored with post and core: effect of design, material, and ferrule*, Dental Research Journal, **13**(3): 233–238, 2016, doi: 10.4103/1735-3327.182182.

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