Three Dimensional Finite Element Analysis Of Different Designs Of Endocrown Retained Bridges Using Different Materials

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Abstract

We used ANSYS Workbench 14 (ANSYS Inc., Canonsburg, PA, USA) software to apply the masticatory forces on our design and we calculate stresses upon our design then we tabulated results to complete our study.

We found that endocrown retained bridge was a successful design of fixed partial dentures according to our study and it can be manufactured from lithium disilicate, zirconia reinforced lithium silicate and zirconia but preferably to be manufactured from zirconia reinforced lithium silicate and lithium disilicate because they presented the most favorable stresses on teeth and less liability to teeth fracture.

Additionally, zirconia reinforced lithium silicate is a promising new type of ceramic that proved according to our study that it can be used in three units posterior bridge construction due to its good mechanical properties as it is used till now in construction of a single tooth restoration only.

Keywords: finite element analysis - Scanning electron microscopic- mesio-occluso-distal palatal- computer aided design/computer aided manufacturer- inlay fixed partial dentures

Introduction

The restoration of endodontically treated teeth is a topic that has been widely and controversially discussed in the dental literature [1], and clinical opinions on this subject have been based on rather empirical philosophies due to the weak link between available scientific data and inconclusive clinical studies [2,3]. Endodontically treated teeth carry a higher risk of biomechanical failure than vital teeth, and are a common problem in restorative dentistry related to the fractures occurring in such teeth [4].

The classical approach in restoring endodontically treated teeth is placement of an intraradiclar post in a tooth with sufficient ferrule, building up a core and construction of a crown and all these elements are retained with each other with adhesive cementation [2,5]. Adhesive cementation increases the strength and the resistance of ceramics to fracture [6].

Recently, endocrown proves its reliability in restoing endodontically treated teeth in molars [7,8] and premolars [9] and this approach if indicated is better than post, core and crown as it is more conservative, than it as it needs minimal invasive preparation with maximal tissue conservation [10]. It proved high success rate and longevity [11-13]

Inlay/onlay retained bridge design is more conservative than the conventional full coverage bridge requiring minimal removal of sound tooth structure as approximately 63% to 73% of the coronal tooth structure is removed when teeth are prepared for all ceramic crowns [14].

This design has high success rate [15] especially with the great advances in adhesive cements [16]. This design proves its success with different all ceramic systems [17,18]. Inlay/onlay retained bridge design is nearly similar to our proposed design of research "Endocrown retained bridge".

Finite element analysis is a widespread method to investigate stress distributions numerically and biomechanical behavior of designs. In the literature, two-dimensional and three-dimensional models of dental restorations can be found [4,19-21]. Hence we used the 3D finite element analysis in our study to evaluate the biomechanical behavior of our design.

Review of Literature

Challenges of endodontically treated teeth:

Endodontically treated teeth are more brittle than vital teeth due to changes in dentin after the endodontic treatment such as loss of water molecules, cross linking of collagen fibrils [22] and due to loss of structural integrity of the tooth caused by caries, trauma and lost during access cavity preparation ending up by cuspal deflection during function and as a result the endodontically treated teeth are more liable to fracture [23,24] and during loading either static or dynamic, cusps deflect with delayed recovery when the load is removed [25,26].

Another issue is the impairment of neurosensory feedback related to the loss of pulpal tissue, which might reduce the protection of the endodontically treated teeth during mastication [13].

Quality and integrity of the remaining tooth structure should be preserved carefully in terms of providing a solid base required for restoration and increasing the structural strength of the restored tooth [27,28]. Biomechanical principles indicate that the structural strength of a tooth depends on the quantity and intrinsic strength of hard tissues and the integrity of the anatomic form. Variations in tissue quality following endodontic treatment proved to have a negligible influence on tooth biomechanical behavior. Mechanically, a conservative endodontic access cavity has been found to minimally affect the fracture resistance of a tooth.

Studies are available showing that the main reason for the decrease in durability is the loss of the marginal ridges [29]. Some researchers reported that endodontic access cavity and root canal preparation resulting in loss of tooth tissue increase the brittleness of teeth, rather than the changes in dentine [29, 30]. In healthy human teeth, a study that compared the effect of endodontic and restorative procedures on cusp durability indicated that endodontic procedures, occlusal cavity preparations and MOD cavity preparations reduce the strength by 5%, 20% and 63%, respectively [31].

Alternatives to restore endodontically treated teeth:

Although there are a number of studies on endodontically treated teeth, treatment planning and the choice of material for the restoration are still controversial, and some criteria must particularly be considered. The remaining coronal tooth structure and functional requirements are important factors to be considered in deciding the treatment planning.

The traditional treatment option for previously endodontically treated teeth is the placement of intraradicular posts to retain the restoration material [23,32]. However, many concerns have been discussed by some authors regarding the pros and cons of post systems.

Post-core Restoration of endodontically treated teeth with extensive coronal loss has followed a strict protocol, with the fabrication of total crowns supported on post-cores. Initially, this protocol was thought to be providing better support for the remaining tooth structure; however, it has been observed that the use of intracanal retainers only increased the retention of prosthetic crowns [2,7]. The purpose of a post-core restoration is to stabilize the remaining coronal tooth structure and to replace missing coronal tissue [1, 2, 33-35]. Some finite element analysis (FEM) studies indicated that a rigid post can strengthen a tooth in its cervical part with the help of totally cohesive interfaces [4, 36], but most studies suggested that posts have no strengthening effect [2].

The characteristics of the interfaces and the rigidity of the materials strongly influence the mechanical behavior of endodontically treated teeth restored with posts, and many authors even discourage the use of posts in consideration of various risks such as root perforation and weakness [2, 4].

Moreover, the placement of posts in root canals could be limited by root anatomy, such as dilacerations or reduced root portions (short roots). Since a post does not strengthen an endodontically treated tooth and the preparation of a post space may increase the risk of root fracture and treatment failure [37] the decision whether to use a post in any clinical situation must be made judiciously.

The practice of endodontic therapy prefers an access cavity preparation that gives endodontic instruments “straight line” access into the canal space. This, along with the concept of “crown down” in endodontic therapy, means that more sound coronal and radicular dentin must be removed for efficient cleaning and shaping of the root canal system. Therefore, the evaluation of whether a post is needed is based on how much natural tooth substance remains to retain a core buildup and support the final restoration after caries removal and endodontic treatment are completed.

Many endodontically treated molars do not require a post because they have more tooth substance and a larger pulp chamber to retain a core buildup. When a post is required as a result of extensive loss of natural tooth substance, it should be placed in the largest and straightest canal to avoid weakening the root too much during post space preparation and root perforation in curved canals. The distal canal of mandibular molars and the palatal canal of maxillary molars usually are the best canals for post placement [38].

When core retention still is insufficient after a single post is inserted, placement of pins can be considered for additional retention. Premolars have less tooth substance and smaller pulp chambers to retain a core buildup after endodontic treatment than do molars, and posts are required more often in premolars. In addition to root taper and curvature, many premolar roots are thin mesiodistally, and some have proximal root invaginations. Furthermore, the clinical crown of the mandibular first premolar often is inclined lingually in relation to its root. These anatomical characteristics must be considered carefully during post space preparation to avoid perforating the root [38].

Few studies have concluded that a post is not necessary in an endodontically treated anterior tooth with minimal loss of tooth structure [35,39,40]. These teeth may be restored conservatively with a bonded restoration in the access cavity [39,41]. A study by ***Baratieri et al*** [42] concluded that the use of posts did not improve the fracture resistance of endodontically treated maxillary incisors that received veneers with direct composite. If an anterior tooth must be prepared to receive a crown after endodontic treatment because a good amount of tooth structure was lost, a post may be necessary to retain the core so that these teeth can resist functional forces. Special care must be exercised when placing posts in mandibular incisors, as they have thin roots in the mesiodistal dimension, which makes post space preparation difficult.

The ideal post and core material should have physical properties such as modulus of elasticity, compressive strength and coefficient of thermal expansion that are similar to those of dentin [43]. Unfortunately, no such material is available to date even though fiber reinforced posts look promising [20].

Fiber post and core:

The enormous development in adhesion paved the way to the use of glass fiber posts. With the development of intraradicular posts made of glass fiber, and directly bonded to dentin, the restoration of endodontically treated teeth became simpler, more economical, and biocompatible [2,40].

The fiber reinforced polymer post is made of carbon or silica fibers surrounded by a matrix of polymer resin, which usually is an epoxy resin. The fibers are 7 to 10 micrometers in diameter and are available in a number of different configurations, including braided, woven and longitudinal. According to two in vitro studies [44,45] the physical strength of fiber reinforced post is significantly weaker than that of cast metal posts and cores. The highly rigid metal would transfer lateral forces without distortion to the less rigid dentin and lead to a higher chance of root fracture. The lower flexural modulus of fiber reinforced posts (between 1and4×106psi), on the other hand, measures closer to that of dentin (≈ 2 × 106 psi) and can decrease the incidence of root fracture [20,44,46].

Fiber reinforced posts are fabricated to bond with most resin cements and resin based composite core materials. In vivo bonding of fiber reinforced posts to the dentinal wall of the root canal space using resin cement has been demonstrated [47,48]. Scanning electron microscopic (SEM) evaluation has shown clearly the formation of a hybrid layer, resin tags and an adhesive