Contents lists available at ScienceDirect

Journal of Prosthodontic Research

journal homepage: www.elsevier.com/locate/jpor

Original article

Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness

Doaa Taha[a,b,*], Sebastian Spintzyk[a], Christine Schille[a], Ahmed Sabet[b], Marwa Wahsh[b], Tarek Salah[b], Jürgen Geis-Gerstorfer[a]

[a] *Section Medical Materials Science & Technology, University Hospital Tübingen, Tübingen, Germany*
[b] *Department of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Cairo, Egypt*

ARTICLE INFO

Article history:
Received 17 July 2017
Received in revised form 14 November 2017
Accepted 23 November 2017
Available online xxx

Keywords:
Endocrowns
CAD/CAM
Polymer infiltrated ceramics
Fracture resistance
Endodontically treated teeth

ABSTRACT

Purpose: The purpose of this in vitro study was to assess the effect of varying the margin designs and the occlusal thicknesses on the fracture resistance and mode of failures of endodontically treated teeth restored with polymer infiltrated ceramic endocrown restorations.
Methods: Root canal treated mandibular molars were divided into four groups ($n = 8$) and were prepared to receive Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) fabricated polymer infiltrated ceramic endocrowns (ENAMIC blocks). Group B2 represents teeth prepared with a butt joint design receiving endocrowns with 2 mm occlusal thickness and the same for group B3.5 but with 3.5 mm occlusal thickness. Group S2 represents teeth prepared with 1 mm shoulder finish line receiving endocrowns with 2 mm occlusal thickness and the same for group S3.5 but with 3.5 mm occlusal thickness. After cementation and thermal aging, fracture resistance test was performed and failure modes were observed.
Results: Group S3.5 showed the highest mean fracture load value (1.27 ± 0.31 kN). Endocrowns with shoulder finish line had significantly higher mean fracture resistance values than endocrowns with butt margin ($p < 0.05$). However, the results were not statistically significant regarding the restoration thickness. Evaluation of the fracture modes revealed no statistically significant difference between the modes of failure of tested groups.
Conclusions: For the restoration of endodontically treated teeth, adding a short axial wall and shoulder finish line can increase the fracture resistance. However, further investigations, especially the fatigue behavior, are needed to ensure this effect applies with small increases of restoration thickness.

1. Introduction

The aim of endodontic treatment is the preservation of root canal affected teeth to prevent their inevitable loss. However, endodontically treated teeth are affected by a much higher risk of biomechanical failure than vital teeth [1,2]. The primary reason for reduction in stiffness and fracture resistance of endodontically treated teeth is the loss of structural integrity associated with caries, trauma, and extensive cavity preparation, rather than dehydration or physical changes in the dentin [3,4]. These biomechanical changes affecting endodontically treated teeth compromise their long term prognosis, making their rehabilitation procedures challenging [5].

To date, there is still no agreement in literature about which material or technique can optimally restore endodontically treated teeth [6]. The classical approach for restoring endodontically treated teeth is to build up the tooth with a post and core, utilizing adhesive procedures and placement of full coverage crowns with a sufficient ferrule [7]. Although prefabricated metal posts allow fast and simple techniques, they do not take into account the individual shape of the root canal and their adaptation is not always ideal. Also, preparation of a post space increases the risk of accidental root perforation [8]. For large and irregular canals, cast metal post build-ups are considered the most suitable solution since they are obtained on the basis of a mold taken directly from the root cavity to obtain the intimate contact between dental canal and post system. However, root fractures may occur because of the high

---

* Corresponding author at: Faculty of Dentistry, Ain Shams University,11566 Cairo, Egypt.
E-mail address: doaataha@asfd.asu.edu.eg (D. Taha).

https://doi.org/10.1016/j.jpor.2017.11.003

Please cite this article in press as: D. Taha, et al., Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness, J Prosthodont Res (2017), https://doi.org/10.1016/j.jpor.2017.11.003

stiffness of metallic alloys commonly used for cast posts in comparison to that of dentin [8]. Since any significant mismatch between stiffness of intraradicular devices and dental tissues will cause large stress concentration at the restorative-materials/tooth interfaces, fiber posts were introduced as customizable post systems made of materials whose elastic properties are very close to those of the natural tooth. This has led to reducing the risk of catastrophic fracture, still debonding as a failure should be considered [8].

A shift in treatment options toward more conservative modalities has been observed recently with the observed advances of adhesive dentistry, questioning the need for conventional post and cores. Ceramic restorations including endocrowns have been introduced as alternative options for restoring endodontically treated teeth depending on the availability of remaining tooth structure [9]. The endocrown is described as a monolithic one piece ceramic restoration, which restores a preparation consisting of a circumferential butt margin and a central retention cavity inside the pulp chamber. This approach utilizes the surface available in the pulp chamber to ensure the stability and retention of a restoration through adhesive bonding [10]. It also follows the concept of decay orientated design leading to minimally invasive preparations [11].

Bindl and Mörmann in 1999 [9] proposed the endocrown as an alternative to the full post and core supported crown. In 2008, Lander and Dietschi [11] presented a clinical report on endocrowns, and in 2009, Magne and Knezevic [12] who were concerned about the choice of reconstruction materials, considered ceramics versus composites for endocrown molar restorations. Various studies suggested extending the concept to maxillary premolars and incisors but these proposals remain controversial [13,14].

This monolithic, ceramic adhesive restoration requires specific preparation techniques to satisfy criteria that are primarily biomechanical in nature. Thus, the preparation for endocrowns is different from that for conventional complete crowns [15]. An endocrown as an adhesive restoration does not require the margin to be placed subgingivally, resulting in less gingival inflammation and recurrent caries [16].

The amount of cuspal coverage which might influence the performance of the tooth restoration complex is a point for further investigation. The usual cuspal reduction varies between 1.5 and 2.0 mm, but limited scientific evidence is available to support this recommendation [17]. Three millimeter thick resin overlays, either generated by Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) or hand layered, also demonstrated a reduced risk of catastrophic failure [18]. The thickness of the ceramic occlusal portion of endocrowns is usually 3–7 mm. An in vitro study showed higher values of fracture resistance of ceramic crowns with increasing occlusal thickness [13].

An important area of interest is the choice of the restorative material. Materials with mechanical properties similar to those of sound teeth improve the reliability of the restorative system [19]. The new polymer infiltrated ceramic material combines the properties of ceramic and polymer. It consists of a hybrid structure with two interpenetrating networks of dominating ceramic and a reinforcing composite forming the so called double network hybrid ceramic material [20]. One of the main advantages of this material as a new dental restorative material is the reasonable brittleness index which makes the material a suitable CAD/CAM candidate; unlike a number of partially sintered CAD/CAM materials which require additional firing. This one step manipulation helps ensure a high degree of dimensional accuracy of the final products. The material also shows lower hardness compared with traditional veneering porcelains which may better protect the opposing teeth from excessive wear and should enable more rapid machining in CAD/CAM machines. Similar creep response as enamel and low hardness grant the material lower contact stresses and good stress redistribution ability when used as a dental restoration [21].

The purpose of this in vitro study was to assess the effect of two margin designs and two occlusal thicknesses on the fracture resistance and mode of failures of endodontically treated teeth restored with polymer infiltrated ceramic endocrown restorations.

The null hypotheses tested were that the fracture resistance values and failure modes would not be influenced either by the different margin designs or by the occlusal thickness.

2. Materials and methods

This work was approved by the committee of Faculty of Dentistry Ain Shams University Research Ethics (FDASU-REC). Recently extracted human mandibular first molars with completely formed apices, without caries or visible fracture lines were selected with similar buccolingual (BL) and mesiodistal (MD) dimensions, as determined with a digital caliper allowing a maximum deviation of 10 % from the determined mean [22]. Afterwards teeth were cleaned with ultrasonic scaler (SUPRASSO P5 Booster ultrasonic scaler, Mérignac, France) then stored at room temperature in 0.1 % thymol solution (Caelo, Hilden, Germany).

All the teeth were endodontically treated by the same operator using the same sequence for the purpose of standardization. The pulp chamber of each tooth was opened following its pulp chamber morphology using a round carbide high speed bur. Protaper system (Dentsply-Maillefer; Ballaigues, Switzerland) was used for root canals treatment for standardization as follow: F2 were used as a master file for the mesial canals, while F3 were used as a master file for distal canals, and sodium hypochlorite was used as an irrigant after each used file. Protaper paper points and gutta percha size F2 were used for mesial canals and size F3 for distal canals. Resin based root canal sealant (ADseal, META BIOMED, Chungbuk, Korea) was used and then a red hot condenser was used for removal of the excess gutta percha.

A surveyor was used to ensure upright position of teeth in molds which were filled with non-shrink epoxy resin material placing the margin of the epoxy resin below the cemento-enamel junction by 3 mm. The selected teeth were randomly divided into four groups ($n = 8$) according to the margin design and occlusal thickness of the restoration All the endodontically treated teeth were prepared using a Computerized Numerical Control (CNC) milling machine (C.N.C Premium 4820, imes-icore, Eiterfeld, Germany) to standardize the preparation dimensions (Fig. 1). For all teeth, the CNC milling machine was adjusted to reduce the pulp chamber with a retention cavity extending 6 mm from the central groove with 8° divergence of the walls. The preparation criteria for each group are shown in (Fig. 2). Group B2 represents teeth that were prepared with a butt joint preparation design and received endocrown with 2 mm occlusal thickness as shown in (Fig. 2A). Group B3.5 represents teeth that were prepared with a butt joint preparation design and received endocrown with 3.5 mm occlusal thickness as shown in (Fig. 2B). On the other hand, group S2 represents teeth that were prepared with axial reduction and 1 mm shoulder finish line and received endocrown with 2 mm occlusal thickness as shown in (Fig. 2C). Lastly, group S3.5 represents teeth that were prepared with axial reduction and 1 mm shoulder finish line and received endocrown with 3.5 mm occlusal thickness as shown in (Fig. 2D). The finished preparations are shown in (Fig. 3).

Endocrown restorations were fabricated using The CEREC AC system (Dentsply Sirona, Bensheim, Germany). Bluecam was used for scanning the preparations and the CEREC 3D Software (version 4.3) for designing the restorations. Standardized endocrowns were milled with the Cerec MCXL milling machine. To standardize the

Please cite this article in press as: D. Taha, et al., Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness, J Prosthodont Res (2017), https://doi.org/10.1016/j.jpor.2017.11.003