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Comparison of fracture resistance between cast, CAD/CAM milling, and direct metal laser sintering metal post systems

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ABSTRACT

Purpose: The purpose of this study was to compare the fracture resistance of Co-Cr post-cores fabricated with 3 different techniques: traditional casting (TC), computer-aided design and manufacturing (CAD/CAM) milling (CCM) and direct metal laser sintering (DMLS).

Methods: Forty intact human mandibular premolar were endodontically treated. The roots were then randomly divided into four groups according to the post systems: the control group was only filled with gutta percha. Co-Cr metal posts were fabricated with TC, CCM and DMLS in the other three groups. The posts were luted with a resin cement and subjected to compression test at a crosshead speed of 1 mm/min. The statistical analysis of the data was performed using one-way analysis of variance (ANOVA) and multiple comparison post hoc Tukey tests ($\alpha = .05$). The samples were examined under a stereomicroscope with $\times 20$ magnification for the evaluation of the fracture types.

Results: The mean fracture loads were 432.69 N for control, 608.89 N for TC, 689.40 N for DMLS and 959.26 N for CCM. One-way ANOVA revealed significant difference between the groups ($p < 0.01$). In the post hoc Tukey test, there were significant differences between groups except DMLS and TC.

Conclusion: While Co-Cr posts fabricated by TC and DMLS systems performed similarly in terms of fracture resistance, posts fabricated by CCM techniques showed higher fracture resistance values.

Significance: Co-Cr metal posts fabricated by CCM and DMLS could be an alternative to TC processing in daily clinical application.

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1. Introduction

Post-core restoration is recommended for endodontically treated teeth when a restoration fulfilling the tooth's masticatory and esthetic functions is not possible using the coronal tissue. Custom cast metal post-cores have long been used to successfully restore teeth [1]. However, despite the arrival of prefabricated post systems, which are recommended due to their fast application, easy manipulation, and advanced physical properties, custom cast metal posts continue to be used [2]. The variable physical properties of post-core systems cause differing stress distributions within the root dentin, which can cause failure of the post, root fracture, or core fracture [3]. Beside these complications, the major factor leading to catastrophic failures (non-repairable) is the elasticity modulus. A rigid post is defined as a cast metal post alloy with a high modulus of elasticity [4]. In vitro studies have shown that the stress distribution is more uniform along the root and coronal structures when the cast-posts are well supported. However, metal cast posts also exhibit high fracture resistance [5,6]. Several metal alloys have been used to manufacture cast posts such as cobalt–chromium (Co-Cr), nickel–chromium (Ni-Cr), and gold alloys due to their hardness, price, and tensile strength. However as an alternate, fiber posts are strong but have significantly less stiffness and strength than metal posts [7]. In the last decade, computer supported technologies for building removable and fixed partial prosthesis, such as computer aided design (CAD) and computer aided manufacturing (CAM), have become very popular. These technologies are used in dentistry to fabricate a variety of prostheses ranging from crowns to long-span fixed partial dentures and removable partial dentures [8]. CAD/CAM milling and direct metal laser sintering (DMLS) are used to fabricate Co-Cr products and these two techniques have decreased cost, eliminated manufacturing (time-consuming processing) and human errors (distortion of wax patterns and irregularities in the cast metal), and improved the accuracy of fitting using the traditional casting technique [9–11]. Intraoral digital scanners with CAD/CAM and rapid prototyping have been popular to fabricate post and core with accelerated techniques [12], whereas DMLS is a popular additive metal fabrication technology that employs a high-power ytterbium (Yb)-fiber optic laser to melt the metal powder, which is then built up layer by layer to a 10–30 μm thickness [9,10]. DMLS technology offers highly accurate construction of fixed partial dentures with fine marginal adaptation and advanced mechanical properties [8]. While studies are directed at marginal and internal fit of metal-ceramic restorations fabricated with CAD/CAM and DMLS [12–14], there is lack of study published on fracture resistance of post-cores fabricated with these techniques. Accordingly, the aim of the present in vitro study is to compare the fracture resistance between cast, CAD and CAM, and direct metal laser sintering metal post systems. The null hypothesis was that no significant difference would be found in the effect of metal post compositions or types on fracture resistance.

2. Materials and methods

Forty extracted non-carious, human mandibular premolar were selected with similar morphology and stored in isotonic 0.9% sodium chloride that contained 0.1% solution thymol crystals until analysis. This study was approved by the ethics committee of Faculty of Medicine, Sifa University. Calculus and soft tissue were removed from the teeth surfaces, and the tooth roots were cut at the cementoenamel junction 12 mm from the root apex to standardize the remaining root length using a diamond disk number (KG Sorensen Ind., e Com. Ltd., Barueri, SP, Brazil) under continuous coolant. After separating the crowns and roots, the mesio-distal (MD) and bucco-lingual (BL) dimensions of the roots were measured with a digital caliper (Mitutoyo Co., Tokyo, Tokyo, Japan) for standardization. Teeth with 6.5 ± 0.3 mm bucco-lingual diameter, 4.7 ± 0.2 mm mesio-distal diameter of the enamel-cementum junction, and teeth ranging 4.8 ± 0.3 mm in bucco-lingual diameter, 3.1 ± 0.3 in mesio-distal diameter in 8 mm from the apex of the enamel-cementum junction were included in the study.

Their weights were measured in a precision scale and the data were evaluated statistically. The root canals were prepared using Reciproc rotary instruments (VDW, Munich, Germany) to a no. 50 file, then smear layer of roots were removed using 17% ethylenediaminetetraacetic acid (EDTA) followed by 5.25% NaOCl and distilled water, and the canals were dried with paper points. All the root canals were obturated with cold lateral compaction technique using epoxy resin-based sealer [AH Plus sealer (Dentsply DeTrey, Konstnaz, Germany)] and gutta percha. All samples were stored in distilled water at 37 °C for 7 days, after which 8 mm of the root canal filling was removed with a Peeso bur at low speed, leaving 4 mm of gutta percha within the root canal with drills (Ultradent, Ultradent USA, South Jordan, Utah) size 2 (1 mm red). The roots were divided into four groups as follows ($n = 10$):

Group C (Control): The root canals were filled with gutta percha and AH Plus sealer.

Group TC (Traditional casting): C-type light and heavy viscosity silicone based impression material (Zeta Plus, Zhermack, Badia Polesine Rovigno, Italy) was mixed and applied inside the root canals with the help of the canal instrument. Post-core modeling was completed on the dental stone model and wax patterns were sprued, invested (Cristobalite; Whip Mix Corp), exposed to the heat in an oven (ECF 44, Eurocem Srl, Milan, Italy) and casted with induction casting machine (INF 2010, Mikrotek Dental, Ankara, Turkey) in the dental laboratory and later post core was fabricated from Co-Cr alloy (Co 61.1%, Cr 27.8%, W 8.5%, Si 1.7%, Mn max 0.5%; Microlit, Schütz Dental, GmbH, Germany) (Fig. 1A).

Group DMLS (Direct metal laser sintering): Root canal impressions that were obtained above were scanned with a digital scanner (D810, 3Shape A/S, Copenhagen, Denmark) to transfer the 3D images to digital design. A computer (Precision T5400 workstation, Dell, Round Rock,