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Porosity distribution in root canals filled with gutta percha and calcium silicate cement

Amir T. Moinzadeh [a], *Wilhelm Zerbst* [a], *Christos Boutsioukis* [a], *Hagay Shemesh* [a], *Paul Zaslansky* [b,*]

[a] *Department of Endodontology, Academic Centre for Dentistry Amsterdam (ACTA), Vrije Universiteit Amsterdam, Gustav Mahlerlaan 3004, 1081 LA Amsterdam, The Netherlands*
[b] *Julius Wolff Institute, Charité-Universitätsmedizin Berlin, Augustenburger Platz 1, 13353 Berlin, Germany*

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ABSTRACT

Objective. Gutta percha is commonly used in conjunction with a sealer to produce a fluid-tight seal within the root canal fillings. One of the most commonly used filling methods is lateral compaction of gutta percha coupled with a sealer such as calcium silicate cement. However, this technique may result in voids and worse, the filling procedures may damage the root.
Methods. We compared the volume of the voids associated with two root canal filling methods, namely lateral compaction and single cone. Micro-computed tomography was used to assess the porosity associated with each method in vitro. An automated, observer-independent analysis protocol was used to quantify the unfilled regions and the porosity located in the sealer surrounding the gutta percha.
Results. Significantly less porosity was observed in root canals filled with the single cone technique (0.445% versus 3.095%, $p < 0.001$). Porosity near the crown of the tooth was reduced 6 fold, whereas in the mid root region porosity was reduced to less than 10% of values found in the lateral compaction filled teeth.
Significance. Our findings suggest that changing the method used to place the endodontic biomaterials improves the quality and homogeneity of root canal fillings.

1. Introduction

Present-day approaches to the treatment of infected root canals combine chemo-mechanical disinfection and creation of a fluid-tight seal [1,2]. Mechanical shaping of the internal root canal walls is necessary so as to make it possible to effectively clean and disinfect these internal root spaces, and to facilitate sealing by placement of designated root canal (endodontic) filling materials. Adequate cleaning as well as complete filling of the root canal spaces are known to promote healing following root canal therapy. To be successful, the filling needs to extend along the entire canal length, ending just shortly shy of the root tip, where the system of canals end and splay [3]. Classical biomaterials used in endodontic therapy are not intended to provide structural/mechanical reinforcement of the roots. Rather, root canal treatment biomaterials are typically biologically inert and have much lower elastic

* *Corresponding author.* Tel.: +49 30 450 559 589; fax: +49 30 450 559 969.
E-mail addresses: a.moinzadeh@acta.nl (A.T. Moinzadeh), wilhelmzerbst@hotmail.com (W. Zerbst), c.boutsioukis@acta.nl (C. Boutsioukis), hshemesh@acta.nl (H. Shemesh), Paul.Zaslansky@charite.de (P. Zaslansky).

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moduli than the tooth tissues that they fill [4]. Their main purpose is to prevent root canal reinfection, providing favorable conditions for post-treatment recovery processes that are expected to take place in the living tissues surrounding the root (the periodontal tissues) [1]. The material most frequently used for sealing human root canals, is a polyisoprene-based material termed gutta percha, the use of which is the standard of care [1]. Gutta percha is available in rigid semi-crystalline cone-shaped forms of various diameters, that can be easily inserted along the prepared root canal space. It can also easily be removed, in the event that root canal retreatment is necessary e.g. in cases of persistent or resistant infections. However, because of the complex shape of the root canal system, even after its preparation, prefabricated gutta percha cones often poorly fit the canal geometry. To solve this problem, slow-setting cements (commonly termed sealers) are used to seal remaining gaps between the cones and surrounding root walls. In order to improve the adaptation of endodontic fillings to the root canal geometry during treatment, mechanical compaction techniques are often used to mold the biomaterials to better fit the prepared empty root canal.

Of the techniques available clinically for root canal treatment, the lateral compaction (LC) method is often quoted as being the gold standard against which other techniques are typically assessed [5]. It is indeed the most common root canal filling technique used by general dental practitioners in the United States [6] and the main root canal filling technique taught in dental schools in Europe. The homogeneity of root canal fillings obtained by LC vary considerably, as they seem to rely on the skills of the dentist. Furthermore and unfortunately, the forces resulting from compacting adjacent gutta percha cones against the internal root walls by the LC method may even induce damage to root dentin [7]. An emerging alternative treatment approach relies on the use of a single cone (SC) technique with wider-taper gutta percha cones. This approach offers an interesting and simple treatment alternative, provided that one obtains an adequate adaptation of the filling material to the root canal geometry. The SC biomaterial-placement technique requires insertion of a properly matched cone in conjunction with a root canal sealer to completely fill the entire canal. It may thus offer a sorely-needed robust treatment alternative that may also potentially reduce the propensity of treatment to damage the dentinal walls [8]. Using both of the above mentioned root canal filling approaches (LC or SC), a sealer is used to completely fill the gaps between the cones and the dental tissues. Several types of sealers are available for this purpose. Of these, calcium-silicate-based root canal sealers are of great interest as they rely on moisture for their setting mechanism and exhibit potential bioactive swelling leading to improved sealing while forming a bond with dentin [9]. Their setting mechanism is based on the absorption of moisture from the surrounding root canal environment [10] and they typically contain zirconium oxide and various calcium-based compounds (Ca_2SiO_4, $Ca(H_2PO_4)_2$, $Ca(OH)_2$). Adequate wetting and full coating of cones and dental surfaces by the sealer remains a treatment challenge, since voids and air bubbles often become entrapped within the filled root canal [11]. Such voids are of great concern because they create porosity, reduce the quality of the filling, serve as hubs for microbial housing and may even link up to tunnel and transport contaminants along the filled root canal. All these lead to re-infection and treatment failure [12] with possible danger of tooth loss.

The aim of this study was to evaluate and compare the voids associated with two endodontic filling techniques, namely the lateral compaction (LC) and single cone (SC) methods. Both methods were used by combining gutta percha and a calcium silicate based sealer. The tested null hypothesis was that there is no difference in the void (%) that result following the application of the 2 filling techniques.

2. Materials and methods

2.1. *Treatment specimen selection*

With the approval of the ACTA dental school ethical committee, 20 maxillary and mandibular human canines, recently extracted for reasons unrelated to the present study, were selected and stored in thymol 0.1% at room temperature. A minimum of 7 teeth per group would suffice to detect a standardized effect of size $r = 0.65$ between the two experimental groups (determined based on the results of a previous study [13]) at 80% power and with a two-tailed probability of α-type error of 0.05. Criteria for tooth selection included the absence of root caries, lack of resorption and calcification of the root canals and a complete (fully formed and undamaged) root tip anatomy. The presence of a single straight (curvature <10°) untreated root canal was confirmed by radiographs examining the bucco-lingual and mesio-distal orientations along the tooth axis. The radiographs were used to estimate the root canal dimensions at 2, 5, 9 and 12 mm from the root tip in order to exclude canals with severe ovality (diameter ratio >2). Root canals presenting unusual anatomy (e.g. a diameter larger than the largest file used during instrumentation, placed to the full canal length) were excluded. The tooth crowns were removed with a diamond bur mounted on a high-speed dental handpiece, to standardize the root lengths to 14 mm.

2.2. *Root canal preparation: Instrumentation and irrigation*

All specimens were prepared and filled by a single operator, according to the following procedures (schematically illustrated in Fig. 1), following standard clinical practices. An ISO size-10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed inside the canal to determine the treatment working length, about 1 mm short of the full root canal length. All root canals were instrumented to a size 40/0.06 taper using a series of nickel–titanium files with increasing diameters (Mtwo, VDW GmbH, Munich, Germany) and a torque-control motor (VDW Silver, VDW GmbH). Consequently, the internal canal diameter was enlarged along the root length, with the widest diameter found in the crown and the narrowest region, $\varnothing = 400 \mu m$, found near the root tip. To remove tissue remnants during instrumentation, the canals were repeatedly irrigated using 2% NaOCl (Denteck, IL Zoetermeer, the Netherlands) after each instrumentation using a 30G needle (NaviTip, Ultradent Products Inc, South Jordan, UT, USA) attached to a syringe (Terumo