Original Article

In Vitro Effect of Flow Rate on Penetration Depth of Thermo-Plasticized Gutta Percha

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Abstract

Background and Aim: Penetration of injectable gutta percha into the root canals is of utmost importance in success of endodontic treatment and is related to the composition, phase and flow of gutta percha. The aim of this study was to evaluate the penetration depth of gutta percha into simulated root canals using 60 and 80 flow rates by BeeFill system.

Materials and Methods: This in vitro experimental study was done on 48 artificial root canals created in the form of a semicircle in a bovine femur. The canals were prepared using FlexMaster rotary instruments according to the manufacturer's instructions for narrow canals and filled with gutta percha and AH26 sealer using BeeFill 60 and 80 flow rates at 180°C with 0.6mm applicator tips to 0.5mm to the working length. Digital images were taken from the root fillings and the root filling penetration depths were determined for each sample. The data were statistically analyzed by independent sample t-test.

Results: The mean penetration depths of thermo-plasticized gutta percha were 2.58mm and 4.83mm for 60 and 80 BeeFill flow rates, respectively. The difference between the two rates was not statistically significant (P=0.69).

Conclusion: Both 60 and 80 BeeFill flow ratesprovided almost similar penetration depth of gutta perchain artificial root canals.

Key Words: Gutta-Percha, Root Canal Obturation, Root Canal Therapy

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Introduction

Root canal anatomy is complex and has irregularities, isthmuses and accessory canals, which may accommodate bacteria and necrotic tissues [1,2]. Due to this complexity, despite recent advances in endodontics, complete cleaning and shaping of accessory canals have not yet been achieved [3].

An efficient root canal treatment requires elimination of all necrotic tissues, microorganisms and residual pulp from the root canal and its shaping for further obturation by root canal filling materials. Root canal obturation and creating a perfect seal are particularly important at the apical third of the root canal [4]. Resistant bacteria in endodontically treated teeth may remain in uninstrumented areas such as accessory canals; in such cases, three-dimensional filling of the root canal system is very important because it prevents re-infection and confines the bacteria in hard-to-reach areas with no access to nutrients [5]. Studies have shown that inadequate apical seal is the most common cause of clinical failure of root canal treatments. Thus, creating a seal at the apical region is extremely important [6-8]. Gutta percha is the most commonly used root canal filling material and is used as a reference for comparison of sealing ability of other root canal filling materials. It is condensable, has adequate dimensional stability, and is biocompatible and radiopaque. It also has a solvent and it is plasticized by heating. However, it cannot bond to dentin, and its poor flexibility results in its separation from the root canals [9].

Lateral compaction is the most commonly used technique for root canal filling [10,11]. Injection is another technique in which, thermo-plasticized gutta percha is injected into the canal by means of special syringes. In comparison with lateral compaction, injection method creates a dense and uniform filling in a short time. Ideal thermoplastic gutta percha must be softened in the lowest temperature causing adequate flow and should maintain its ability to solidify when cools down to body temperature [12]. Several systems have been introduced for this purpose such as Obtura II, Calamus, Element, System B and BeeFill. In these systems, the flow and temperature of device are adjustable [4]. Several studies have evaluated the efficacy of different systems in filling of intracanal defects and voids; density of filling and the amount of gutta percha or sealer used have also been evaluated, showing differences in this regard among different systems [13]. Some studies showed that in injection method, gutta percha better penetrates into canal walls and accessory canals compared to the lateral compaction technique [4,6,14,15]. The efficacy of thermoplastic gutta percha in C-shaped canals, internal resorption defects, accessory canals and numerous canal communications has reported to be optimal [6]. Moreover, Karabucak et al. reported that flow of root canal filling material into accessory canals mainly depends on viscoelastic properties of the material rather than mechanical properties of the system used [16]. Moon et al. stated that when heating the samples to 60°C, a significant reduction in penetration resistance occurs. It has been shown that this thermoplastic behavior is due to the transformation of crystalline phase of gutta percha polymer to non-crystalline phase [12].

Penetration of injectable gutta percha into root canals is important in success of endodontic therapy and factors such as canal curvature, flow of material and gutta percha phase are effective in this regard [8]. Previous studies on this topic did not reach a definite conclusion regarding optimal curvature and flow in endodontic treatments. Since the current ISO standard for root filling materials only covers prefabricated points and cones and is not applicable to thermoplastic filling materials [12] as well as the significance of achieving an optimal seal in endodontic treatments, this study aimed to compare the penetration depth of thermo-plasticized gutta percha into simulated root canals using 60 and 80 flow rates of BeeFill system.

Materials and Methods

This in vitro study was conducted on 48 single canals created in bovine bone. Sample size was calculated to be 22 in each of the two groups using the formula for comparison of two means according to the results of a pilot study assuming 80% power, difference (d) of 0.6 between the mean penetration depths in the two groups of 60 and 80 flow rates and significance level of 0.05. To increase the accuracy of results, 24 samples were evaluated in each group.

Samples were randomly divided into two groups of 24. Bone blocks measuring 10cm in height and 8 cm in width were obtained using bovine femur bone (mature, male cows) because it has a physical and chemical structure similar to that of dentin [17,18]. After primary cleaning (using 5.25% sodium hypochlorite for 10 minutes), the samples were stored in water in plastic containers for 24 hours. Eight grooves with 0.2mm depth and 6mm diameter were created on each block using trephine bur (Meisinger Co., Neuss, Germany) in semi-circular shape (Figure 1). In order to create artificial root canals along each groove, a Flex Master file (VDW, Munich, Germany) was used according to the manufacturer's instructions for narrow canals using an endodontic micro-motor control unit (VDW Gold; VDW Co., Munich, Germany) and a handpiece (Siemens, Munich, Germany) in 1:1 ratio.

After creating artificial canals in six bone blocks (a total of 48 canals), samples were randomly divided into two experimental groups as follows:

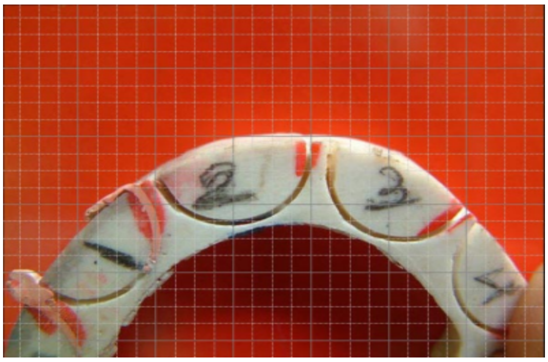

Figure 1. Semi-circular grooves created on bone blocks

Group one: In this group, AH26 sealer (Dentsply Maillefer,Ballaigues, Switzerland) was applied to root canals and they were then filled using BeeFill with 0.6mm applicator tip up to 5mm to working length at 60 flow rate.

Group two: In this group, AH26 sealer (Dentsply Maillefer,Ballaigues, Switzerland) was applied to root canals and they were then filled using BeeFill with 0.6mm applicator tip up to 5mm to working length at 80 flow rate.

To prevent extrusion of gutta percha during filling of root canals, a glass slab was placed over each bone block. After filling of root canals, digital images were obtained of all samples in the two groups using a digital camera (Fujifilm, Tokyo, Japan) at x6 magnification and 6 Megapixels accuracy and penetration depth of gutta percha was determined linearly on images and reported in millimeters. Canals in which, thermo-plasticized gutta percha passed the apex weremarked as (+) and those in which, gutta percha did not reach the canal end weremarked as (-).

Data were statistically analyzed using SPSS version 15.0 (SPSS Inc., IL, USA).

Kolmogorov-Smirnov test showed that penetration depth of gutta percha in both groups had a normal distribution (P=0.77). Thus, independent sample t-test was applied for comparison of independent groups. P≤0.05 was considered statistically significant.

Results

The results showed that in both 60 and 80 flow rates, thermo-plasticized gutta percha passed the canal end in 12 root canals (50%); in the remaining 50%, thermo-plasticized gutta percha did not reach the root canal end. In other words, no significant difference was noted between the two groups in this regard (P>0.05). Assessment of penetration depth of gutta percha in use of BeeFill at 180°C at 60 and 80 flow rates showed that the mean penetration depth of gutta percha was 2.58mm in 60 and 4.83mm in 80 flow rates. Despite higher mean penetration depth of gutta percha at 80 flow rate, the difference in this regard between the two groups was not significant (P=0.69). The mean and standard deviation of gutta percha penetration depths are shown in Table 1. Table 2 presents the results of Student's t-test.

Discussion

In use of BeeFill, gutta percha is available in aluminum carriers, which are placed in heat carrier system. Gutta percha is heated to 185-200°C. Also, 60mm and 80mm needles or applicator tipshave been designed to carry thermo-plasticized gutta percha and deliver it to the apical and middle thirds of the root canal to 5mm distance from the working length [13]. Root canal filling methods based on preheated gutta percha aim to improve the quality of three-dimensional root filling [4,5].

Use of liquid root filling materials increases the risk of overfilling of root canal and can stimulate periapical tissue. In contrast, when materials have high viscosity, root canal system may not be adequately filled and risk of gap formation increases. Moreover, high-viscosity materials require manual application of high pressure by dentist [19]. Considering the significance of penetration of gutta percha into the root canal system to create an optimal seal (which plays an important role in success of endodontic treatment), penetration depth of thermo-plasticized gutta percha in BeeFill system at 60 and 80 flow rates was evaluated in this study. These values were selected since they have been recommended to increase the penetration depth of gutta percha into narrow canals. Artificial root canals in this study were also created based on available instructions for narrow canals.

Table 1. The mean, standard deviation, minimum and maximum penetration depth of gutta percha in millimeters in 60 and 80 flow rates

Flow rate	Mean	SD*	SE**	Minimum	Maximum	Median
60	2.58	17.69	3.61	-22	42	0.5
80	4.83	21.67	4.42	-25	47	1.5

* **Standard deviation**
** **Standard error**

Table 2. Comparison of penetration depth of gutta percha in use of BeeFill with 60 and 80 flow rates (Student's t-test)

Index		Value
t		-0.394
Degree of freedom		46
P value		0.695
Mean difference between the two groups		-2.25
Standard error		5.71
95% confidence interval	Lower bound	-13.74
	Upper bound	9.64

Although type of gutta percha and its formulation can affect its penetration depth and its ability of filling the root canal system, one type of gutta percha was used in this study to control for this confounding factor. The mean penetration depth of gutta percha at 80 flow rate was about two times the value at 60 flow rate. Despite higher penetration of gutta percha at 80 flow rate, the difference in penetration depth was not significant between the two groups, which may be due to high standard deviation of penetration depth values. It means that both 60 and 80 flow rates of BeeFill system result in relatively similar penetration depth of gutta percha in narrow canals.

Changes in the mean penetration resistance of materials can be due to differences in their chemical properties (such as mean molecular weight, distribution of molecular weight and crystallization), organic components such as gutta percha polymer, wax, resins and plasticizers as well as mineral chemical parameters such as zinc oxide, barium sulfate and other fillers [12]. Studies have shown that the ability of gutta percha for penetration into root canals depends on its chemical formulation and may be different for different brands of gutta percha [20,21]. Gutta percha commercially available in the market is composed of organic polymers and inorganic (zinc oxide and barium sulfate) compounds. Gurgel-Filho et al. [21] showed that use of lower percentage of polymer in composition of gutta percha can result in a reduction in its flexibility and consequent limitation in its penetration depth into root canals.

Contraction of thermo-plasticized gutta percha occurs when it cools down to 37°C; this decreases its penetration depth [22]. Gutta percha also has two phases of alpha and beta and alpha phase gutta percha has low melting point and good adhesion while beta phase gutta percha has high melting point and no adhesion. Thus, change in melting point of gutta percha in the two phases results in change in its rate of contraction. This affects the sealing ability of gutta percha and its penetration depth into the root canals.

Karabucak et al. evaluated the penetration depth of gutta percha and Resilon into accessory root canals following the use of different thermo-plasticized gutta percha systems and showed that penetration depth of root filling materials into accessory canals mainly depended on the viscoelastic properties of the material itself rather than the mechanical properties of the system used for injection of gutta percha [16]. Moon et al. introduced Obtura with hard and moderate consistency as low flow materials while BeeFillObtura with soft consistency and Tactendo (carrier based system) were categorized as high flow materials. This classification was based on melt-flow temperature (threshold temperature at which, penetration resistance reaches to less than 0.15 MPa) [12].

Use of thermo-plasticized gutta percha was first described by Schilder in 1967 and was then modified [23]. Some studies have shown that condensed thermo-plasticized gutta percha has higher adaptation to root canal walls compared to lateral compaction technique [2,4-5,14,15].

In the study by Karabucak et al, similar to the current study, artificial root canals of plastic teeth were used to assess the penetration depth of gutta percha [16]. However, Goldberg et al, [24] and Carvalho et al. [5] stated that use of extracted human teeth instead of artificial root canals better simulates the oral clinical setting [5,24].

Gutta percha penetration depth also depends on the type of sealer used, method of sealing, method of assessment of penetration depth and laboratory conditions [25]. In order to achieve optimal seal in root canal filling, sealer must be necessarily used. Sealer enhances the flow of gutta percha and results in better penetration of thermo-plasticized gutta percha [26]. In a study by Wu et al, [27] AH26 sealer significantly increased the seal of fillings. However, in our study, the effect of sealer type was controlled for in the two groups since the same type of sealer was used in the two groups.

In the current study, digital images were obtained to determine the penetration depth of gutta percha into root canals. Diemer et al. [28] evaluated the effect of apical preparation on penetration depth of gutta percha pluggers and De-Deus et al. [29] evaluated the sealability of gutta percha-EWT and Resilon/Epiphany in oval-shaped canals both with the use of digital images to determine the penetration depth of gutta percha.

For optimal seal, master gutta percha cone must well adapt to canal walls [30]. This adaptation is related to temperature, application time and penetration depth of gutta percha [31]. Smith et al. [32] reported that heating of thermo-plasticized gutta percha must extend to 3mm of working length in order for the master gutta percha cone to smoothen and well adapt to the canal walls. This issue was also mentioned by Bowman and Baumgartner [33]. In use of BeeFill in the current study, pluggers freely penetrated to 5mm to working length as recommended by the manufacturer.

Due to complex anatomy of the root canal system, even the most advanced cleaning and shaping techniques cannot efficiently eliminate all the bacteria and stimuli from the root canal system [34]. Thus, role of materials and methods used for filling and sealing of root canal system is extremely important in success of endodontic treatment.

The current results provided an estimate regarding penetration depth of thermo-plasticized gutta percha in use of 60 and 80 flow rates of BeeFill. Future studies with temperatures other than 180°C used in this study, different sealers and different methods are required to better elucidate this topic. Also, the results of using this system must be compared with those of other thermoplastic systems to find the ideal system enabling highest penetration depth of gutta percha into root canals. Moreover, clinical studies are required to confirm these results prior to their generalization to the clinical setting.

Conclusion

Within the limitations of this study, the results showed that both 60 and 80 flow rates resulted in relatively similar penetration depth of thermo-plasticized gutta percha into simulated narrow root canals.

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