

Effect of canal taper and plugger size on warm gutta-percha obturation of lateral depressions

Wu Zhang¹⁾, Hisashi Suguro^{2,3)}, Yoshimi Kobayashi⁴⁾, Tamotsu Tsurumachi^{2,3)}
and Bunnai Ogiso^{2,3)}

¹⁾Department of Endodontics, Shandong University School of Dentistry, Jinan, China

²⁾Department of Endodontics, Nihon University School of Dentistry, Tokyo, Japan

³⁾Division of Advanced Dental Treatment, Dental Research Center, Nihon University School of Dentistry, Tokyo, Japan

⁴⁾Division of Applied Oral Sciences, Nihon University Graduate School of Dentistry, Tokyo, Japan

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Abstract: This study used transparent epoxy-resin root canal models to evaluate different main root canal tapers and various methods of vertical compaction for warm gutta-percha obturation of lateral depressions. The root canal models had straight main root canals with three tapers and four lateral depressions at right angles to the main root canal, 1.0 mm and 3.0 mm from the apex. Three types of experimental stainless steel pluggers with different flat-tip diameters and tapers were used to compact the warm gutta-percha. The Obtura II was used for obturation. After obturation, the depth of penetration into lateral depressions was measured under a stereoscopic microscope, and the effects of root canal taper and plugger size were analyzed by using two-way analysis of variance. The penetration of warm gutta-percha into lateral depressions using the smallest-diameter plugger decreased with increasing main root canal taper. Penetration into lateral depressions increased with the use of pluggers of the correct size. There was a close relationship between plugger size and canal taper. The results suggest that main root canal taper and plugger size should be closely matched so as to promote gutta-percha obturation of lateral depressions.

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Keywords: warm vertical compaction; plugger size; root canal tapers; lateral depression; penetrated distance.

Introduction

Successful endodontic therapy requires preparation of an aseptic root canal and sealing of the root canal system to prevent microbial leakage (1-3). Aseptic conditions are created in the root canal system by means of serial root canal treatments using chemomechanical root canal preparation, disinfection, and root canal obturation (4,5). One goal of endodontic therapy is root canal obturation, the main objectives of which are hermetically sealing the root canal system and preventing re-infection by microorganisms via the root canal orifice and apical foramen (6). Inadequate root canal obturation can ultimately lead to failure of endodontic treatment (7,8). Lateral compaction using gutta-percha cones and root canal sealers is an accepted method for root canal obturation (9,10); however, its ability to achieve hermetic sealing has been questioned, as this technique uses a solid core cemented with root canal sealers that have unfavorable properties, such as solubility and shrinkage (11).

At present, various vertical compaction methods are used for well-filled root canal obturation (12-15). These methods result in optimal three-dimensional filling of anatomically complicated root canal systems. Many reports

Correspondence to Dr. Hisashi Suguro, Department of Endodontics, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan
Tel: +81-3-3219-8142
Fax: +81-3-3219-8348
E-mail: suguro@dent.nihon-u.ac.jp

have confirmed the contribution of vertical compaction methods to hermetic sealing and stability and have proposed improvements for obtaining greater hermetic compaction (12-15). Thus, evaluation of three-dimensional filling of the root canal is extremely important. We designed transparent epoxy resin root canal models comprising straight main root canals with three tapers and four lateral depressions. The purpose of this study was to evaluate the relationship of root canal taper and plugger size to gutta-percha obturation of lateral depressions using a vertical compaction technique.

Materials and Methods

Experimental root canal models

We used transparent epoxy resin root canal models (root canal model, $15.0 \times 15.0 \times 18.0$ mm, Nissin Dental Products, Kyoto, Japan) with three different tapered main root canals (0.08, 0.16, and 0.24 tapers) and four 0.5-mm-diameter lateral depressions at right angles to the main root canal located 1.0 mm and 3.0 mm from the apex (Fig. 1).

The main root canal was straight, with a standardized length of 17.0 mm and an apical foramen 0.3 mm in diameter, and the apical seat was originally prepared to a #80 size file. Five root canal models for each taper were used in experiments 1 and 2. The patency of all lateral depressions and apical foramina was ensured before warm gutta-percha obturation.

Pluggers

Three types of experimental stainless steel pluggers (YDM, Tokyo, Japan) with different flat tip diameters

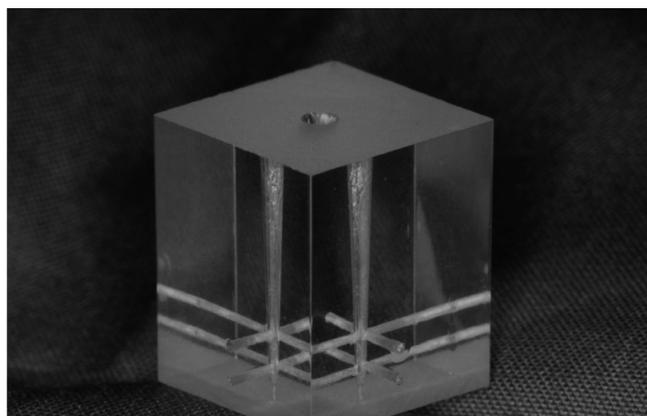


Fig. 1 Photo of root canal model (taper 0.08). In this study, we used transparent epoxy resin root canal models comprising three different tapers of the main root canals (0.08, 0.16, and 0.24 tapers) and four lateral 0.5-mm-diameter depressions at right angles to the main root canal located 1.0 mm and 3.0 mm from the apex.

(1.2, 1.6, and 2.0 mm) and tapers (0.08, 0.16, and 0.24 tapers) were used to compact the warm gutta-percha (Fig. 2).

Obturation method

For each tapered root canal model, an Obtura II needle (diameter, 0.88 mm; Obtura Corp., Fenton, MO, USA) was inserted into the main root canal to a point 3.0 mm from the apex. Then, adequately heated, warm (200°C) gutta-percha was carefully injected to 6.0 mm from the apex with no vertical pressure. No root canal sealer was used in this study.

The placement of the pluggers was maintained at 5.0 mm from the apex after injecting the warm gutta-percha. Thereafter, vertical compaction was performed immediately and consisted of a one-time compaction for 60 s.



Fig. 2 Three types of experimental stainless steel pluggers with different flat-tip diameters (1.2, 1.6, and 2.0 mm) and tapers (0.08, 0.16, and 0.24) were used to compact the warm gutta-percha.

a) 1.2 mm diameter and 0.08 taper, b) 1.6 mm diameter and 0.16 taper, c) 2.0 mm diameter and 0.24 taper.

Experiment 1: Effects of root canal taper

Using a 1.2-mm-diameter plugger with a 0.08 taper, vertical compaction was performed in the three different taper root canal models. Warm gutta-percha injected into the main root canal was compacted with the plugger to a point 5.0 mm from the apex. Vertical compaction was applied once at 1.0 kg (9.8 N) for 60 s. Five root canal models of three different tapers were used for each experimental condition. The compaction methods were the same as in experiment 1 and 2. All root canal models were stored at 36°C and 100% humidity for 24 h after obturation.

To evaluate obturation of the lateral depressions, penetration of the warm gutta-percha into the lateral depressions 1.0 mm and 3.0 mm from the apex was measured. The distance from the outer surface of the main root canal to the limit of the obturated gutta-percha in the lateral depression at the center line was measured for every depression under a stereoscopic microscope ($\times 10$, Leica MZ FILL, Leica Corp., Wetzlar, Germany), and the average value of 20 lateral depressions was used as the obturation distance at each point.

Experiment 2: Effects of plugger size

Pluggers of three different sizes were used to perform vertical compaction individually in different root canal models. A 1.2-mm-diameter, 0.08-taper plugger; a 1.6-mm-diameter, 0.16-taper plugger; and a 2.0-mm-diameter, 0.24-taper plugger were used for the 0.08-, 0.16-, and 0.24-taper root canal models, respectively.

Statistical analysis

Statistical analysis was performed using the two-way ANOVA test followed by the Tukey test. Differences were considered significant at $P < 0.05$.

Results

The results of experiment 1 are shown in Table 1. The depth of penetration into lateral depressions at both 1.0 mm and 3.0 mm decreased with increasing taper of the main root canal ($P < 0.05$). There were significant differences between the 0.08 and both the 0.16 tapers and 0.24 tapers at both 1.0 mm and 3.0 mm ($P < 0.05$). There was no significant statistical difference between the 1.0-mm and 3.0-mm points for any taper ($P > 0.05$).

The results of experiment 2 are shown in Table 2. The depth of penetration into the lateral depression was similar at both 1.0 mm and 3.0 mm. There were no significant difference among the experimental conditions with the exception of a significant difference between the 0.08 taper and 0.24 taper at 1.0 mm ($P < 0.05$).

Table 1 Experiment 1: Comparison of differences in taper degree

Depression level	3 mm (mm)	1 mm (mm)
Taper 0.08	1.62 (0.07) ^a	1.57 (0.04) ^a
0.16	0.50 (0.19) ^b	0.54 (0.09) ^b
0.24	0.46 (0.22) ^b	0.48 (0.34) ^b

$n = 5$. If marked by a different letter, the difference between groups is statistically significant ($P < 0.05$). Values are expressed as mean (SD).

Table 2 Experiment 2: Comparison of differences in size of plugger

Depression level	3 mm (mm)	1 mm (mm)
Taper 0.08	1.62 (0.07)	1.57 (0.04) ^a
0.16	1.69 (0.29)	1.69 (0.10)
0.24	1.76 (0.07)	1.77 (0.10) ^b

$n = 5$. If marked by a different letter, the difference between groups is statistically significant ($P < 0.05$). Values are expressed as mean (SD).

Table 3 Comparison of difference in depression level (3.0 mm)

Depression level	Experiment 1 (mm)	Experiment 2 (mm)
Taper 0.08	1.62 (0.07)	1.62 (0.07)
0.16	0.50 (0.19) ^a	1.69 (0.29) ^b
0.24	0.46 (0.22) ^a	1.76 (0.07) ^b

$n = 5$. If marked by a different letter, the difference between groups is statistically significant ($P < 0.05$). Values are expressed as mean (SD).

Table 4 Comparison of difference in depression level (1.0 mm)

Depression level	Experiment 1 (mm)	Experiment 2 (mm)
Taper 0.08	1.57 (0.04)	1.57 (0.04)
0.16	0.54 (0.09) ^a	1.69 (0.10) ^b
0.24	0.48 (0.34) ^a	1.77 (0.10) ^b

$n = 5$. If marked by a different letter, the difference between groups is statistically significant ($P < 0.05$). Values are expressed as mean (SD).

The results for depression levels of 3.0 mm and 1.0 mm are shown in Tables 3 and 4. There were significant differences between experiment 1 and experiment 2 for both the 0.16 taper and 0.24 taper ($P < 0.05$).

Discussion

Obturation of the root canal system, ie, the final stage of root canal treatment, is an integral part of successful endodontic therapy that affects long-term prognosis, as do ideal root canal cleaning, preparation, and disinfection (4,5). Various vertical compaction methods using warm gutta-percha have been widely used for this purpose (12-15). Many studies have examined the sealing effects of various three-dimensional root canal obturation techniques, including conventional lateral compaction technique (12-16). Weine (7) reported that the type of filling technique did not have an important effect on the obturation of lateral canals. However, Brothman (17) demonstrated that vertical compaction of warm gutta-percha approximately doubled the number of filled lateral canals when compared with lateral compaction of gutta-percha.

Most authors have examined how compaction technique and adequate root canal preparation facilitate suitable root canal obturation with warm gutta-percha (6,16-20). Since its introduction by Schilder (21), vertical compaction has been used to improve sealing ability. Schilder maintained that the objective of root canal filling procedures should be total three-dimensional filling of the root canal and all accessory canals. The root canal has a complex morphology with many irregularities, including fins, deltas, accessory canals, and lateral canals. Lateral canals have been shown to be present in 27.4% to 45% of teeth, with the majority located in the apical third of roots (22).

This study investigated the effects of root canal taper and plugger size on the extent of obturation using transparent epoxy resin root canal models comprising main root canals with three different tapers and lateral depressions.

Previous studies have used experimental root canal models or extracted teeth to investigate the extent of obturation (16-20). However, the disadvantages of these studies were that the models had to be split for the investigation, and the resulting two-dimensional assessment was limited. To overcome these shortcomings, the use of nondestructive root canal models would be beneficial. In addition, no studies have investigated the depth of penetration of gutta-percha obturation of a lateral depression of the root canal system. Thus, in this study, three-dimensional obturation of the root canal model system was extremely important.

Obtura II was used as the warm gutta-percha compaction method for this study. This system consists of a control unit and a handheld gun that contains a chamber surrounded by a heating element into which a pellet of gutta-percha is loaded and heated to a minimum temperature of 160°C. When plasticized, the gutta-percha is injected through a

silver needle into the prepared root canal. A drawback of this technique is the inability to control apical extrusion of the softened gutta-percha (16).

The extrusion of these models does not allow apical flow of gutta-percha. In this study, the placement of every plugger was controlled at 5.0 mm from the apex. Yared and Bou Dagher (23) confirmed that pluggers must be inserted to within 5.0 to 7.0 mm of the apex to achieve efficient gutta-percha condensation and a tight apical seal. In this technique, vertical force transmitted via the plugger plays a crucial role in compacting the melted gutta-percha into the main and accessory canals. Theoretically, the ease of penetration of the plugger depends on the size and taper of the preparation instrument. Diemer et al. (24) suggested that the insertion depth of the plugger was restricted by canal anatomy and that the plugger should penetrate the canal to a depth sufficient to obtain favorable vertical obturation.

In a clinical setting, variation in natural canal shape might block insertion of a plugger and prevent compaction of gutta-percha, even with adequate root canal preparation. Therefore, the choice of plugger size after ideal root canal preparation is important for obtaining adequate vertical root canal obturation.

In this study, the relationship between the main canal taper and plugger size was investigated by measuring the penetration of warm gutta-percha into lateral depressions. The results showed that plugger size and canal taper were closely related to gutta-percha compaction in the main root canal and lateral depressions, which suggests that canal taper and plugger size should be closely matched to promote better obturation of lateral depressions with uneven root canal surfaces.

In addition, vertical compaction force is an important factor in obtaining better obturation. In this study, a vertical compaction force of 1.0 kg (9.8 N) was applied to the plugger for 60 s at each compaction. The compaction force used during obturation was controlled by performing all obturation procedures on a scale, using a force that was less than 2.0 kg. Some reports have indicated that excessive forces generated during compaction contributed to vertical root fractures (25,26). However, Lindauer et al. (27) reported that the range of forces commonly used by endodontists (1.0-3.0 kg) and those of greater magnitude (≤ 4.9 kg) did not lead to fracture of mesial roots of mandibular molars. Onnick and Davis (28) stated that obturation using lateral compaction and thermoplasticized material did not result in more root fractures as compared with uninstrumented or unobturated root canals.

In a clinical setting, however, it is important to consider the temperature of the heated gutta-percha flowing into the

root canal and the effects of a root canal sealer on regulating the temperature of the gutta-percha. A future study should investigate the effects of root canal sealer on the penetration of warm gutta-percha into lateral depressions. Such research should measure depth of penetration using curved root canals. It would be also be beneficial to compare results obtained from root canals with different degrees of curvature.

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