Effect of Different Obturation Techniques on Sealer Penetration in Teeth with Artificial Internal Root Resorption: a Confocal Laser Microscope Analysis

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Objective: *To investigate the efficacy of different obturation techniques on sealer penetration in teeth with internal root resorption using confocal laser microscopy.*

Methods: *An artificial internal resorption cavity (3 mm deep and 1.2 mm in diameter) was formed in the round-shaped root canals of 45 single-rooted teeth at a distance of 7 mm from the apex, then roots were instrumented (size 40/.06). The samples were divided into three groups (n = 15) according to the obturation technique: lateral compaction (LC), warm vertical compaction (WVC) and carrier-based (CB).*

Results: *In the resorption regions, the sealer penetration depth in the CB and LC groups was significantly higher than that in the WVC group (P < 0.05).*

Conclusion: *Within the limitations of this study, the penetration depth of the sealer in the resorption region was higher in the CB and LC groups as compared to that in the WVC group.*

Key words: *carrier-based technique, internal root resorption, sealer penetration, warm vertical compaction*

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Internal root resorption (IRR), which is the result of various factors, such as chronic infection and trauma, is characterised by the gradual destruction of the dentine along the root canal walls[1]. IRR is not always clinically symptomatic and is thus often detected during routine radiographic examinations. In teeth with IRR, the root canal space or pulp chamber is enlarged on radiographs[2]. Endodontic treatment can be performed in teeth with IRR considering restoration and prognosis[1]; however, 3D chemomechanical shaping and obturation of the resorption area can be difficult for endodontic treatment in teeth affected by it[3]. According to the literature, insufficient root canal obturation in teeth with IRR causes bacterial leakage and consequent apical periodontitis[4]. Thus, the prognosis of endodontic treatment in teeth with IRR depends on the selection of an appropriate obturation technique[4,5]. The current available obturation techniques include lateral compaction (LC), warm vertical compaction (WVC) and carrier-based (CB) techniques.

The LC obturation technique allows gutta-percha to be placed in the root canal in a controlled manner, but also has disadvantages, such as a long application time, lack of homogeneity of obturation due to the formation of gaps between the gutta-percha, inadequate adaptation to root canal walls, and an increased risk of vertical root fracture[6,7]. Previous studies reported that LC, which is widely used in clinical practice, is insufficient to provide 3D obturation in the IRR cavity[8]. Thus, the use of alternative obturation methods for LC in teeth with IRR has been proposed[9].

WVC is a hybrid root canal obturation technique that involves the combined use of downpacking and back-fill procedures. Using this technique, the apical portion of the root canal is filled using a down-packing unit. The remaining root canal cavity is obstructed by the back fill unit, which allows the gutta-percha to be applied in a controlled manner[10,11]. Using this tech-

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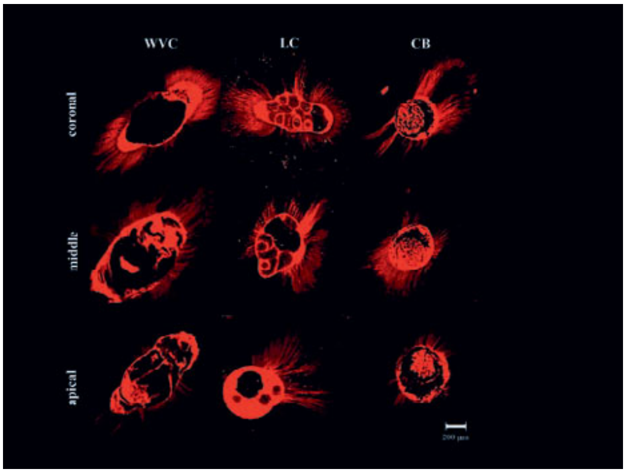

Fig 1 CLSM images representative of sealer penetration in the apical, middle and coronal region for each group.

nique, gutta-percha, which becomes fluent with the application of heat, adapts to root canal irregularities and the root canal walls[12,13].

The CB obturation technique involves the use of thermoplasticised gutta-percha as root obturation material. This material consists of a plastic or crosslinked gutta-percha carrier coated with α-phase gutta-percha[14]. In this technique, root canals are obturated using a homogeneous gutta-percha mass[15]. Selection of an appropriate obturation method to ensure hermetic obturation of the resorption area in teeth with IRR, which is difficult to manage clinically, is important with regard to the treatment prognosis[16,17]. In the present study, we investigated the effect of different obturation techniques on root canal sealer penetration in teeth with IRR.

The aim of this study was to investigate the influence of different obturation techniques on sealer penetration in teeth with artificial internal root resorption through confocal laser microscopy (CLSM).

Materials and methods

The study design was approved by the local ethics committee (ethics committee no. 2019/191). Forty-five teeth with round-shaped canals and without root caries, resorption, fractures, cracks or root canal treatment were included in this study. After removing the crowns under water cooling, the root length was standardised to 15 ± 1 mm. Using a diamond disc, the roots were divided into two parts at a distance of 7 mm from the apex. To simulate the resorption defect on the surfaces facing each other of both parts, a resorption cavity (1.5 mm deep and 1.2 mm in diameter) was prepared using a low-speed diamond cylindrical bur[9]. Two sections of each sample were joined from the outer root surface using flowable composite resins without using a dental bonding agent so that they were in the initial position, then the LED light was used for polymerisation of the composite. The working length was determined using a #10 K-type file (Dentsply Maillefer, Ballaigues, Switzerland) that was 0.5 mm shorter than the apex. After the teeth were embedded in the alginate (Blueprint, Denstply Sirona, Charlotte, NC, USA) to simulate the resistance of periodontal tissues, the root canals were prepared using ProTaper Next Rotary X1, X2, X3 and X4 files (Dentsply Maillefer)[18,19]. The root canals were irrigated with 2.5 ml 2.5% NaOCl (Wizard; Rehber Kimya, Istanbul, Turkey) after each file change, then 5 ml 2.5% NaOCl, 5 ml 17% ethylenediaminetetraacetic acid (Wizard; Rehber Kimya) and 5 ml distilled water were used for the final irrigation procedure. The procedure was carried out using a sideport irrigating needle (NaviTip; Ultradent, South Jordan, UT, USA). The root canals were dried with paper points (Diadent, Chongju, South Korea). The samples were randomly divided into three groups (n = 15) according to the root canal obturation technique used.

For the LC group, gutta-percha (ISO 40, 0.2 mm; Diadent) was coated with a sealer (AH Plus; Dentsply DeTrey, Konstanz, Germany) labelled with 0.1% rhodamine B dye (Sigma Aldrich, St Louis, MO, USA) and placed in the canal. Using 25, 20 and 15 finger spreaders (Dentsply Maillefer), gaps were created in the root canal and accessory cones were then placed. The canal was deemed to be sufficiently obturated when no more spreaders could be placed in the canal orifice[10].

For the WVC group, ProTaper X4 gutta-percha (Dentsply Maillefer) was coated with AH Plus sealer, labelled with 0.1% rhodamine B dye (Sigma Aldrich Co.) and placed in the canal. A Buchanan Heat Plugger Fine 0.04 taper (Kerr Dental, Orange, CA, USA) connected to the down-pack unit of an elements Free Obturation System (Kerr Dental) was adjusted to be 4 mm shorter than the working length. The down-packing was carried out by advancing the Buchanan Heat Plugger Fine 0.04 taper in an apical direction. The elements Gutta Percha Cartridge (Kerr Dental) was heated to 200°C. The remaining root canal space was gradually obturated with gutta-percha using the back-fill unit (Kerr Dental). A size 9 posterior Schilder plugger (Dentsply Maillefer) was used to condense the gutta-percha in an apical direction.

For the CB group, using a ISO 40, 0.2 mm paper point (Diadent), the canal walls were covered with AH Plus sealer and labelled with 0.1% rhodamine B dye. A size 40 Thermafil Plus obturator (Dentsply Sirona) was prepared in a ThermaPrep 2 Oven (Dentsply Sirona)

Table 1 Mean values and standard deviations (SD) of the sealer penetration depth (mm) into the dentinal tubules.

Region	WVC	LC	CB
Apical	0.232 ± 0.188^{Aa}	0.508 ± 0.400^{Aa}	1.096 ± 0.606^{Ab}
Middle	1.279 ± 0.743^{Ba}	2.225 ± 0.636^{Ab}	1.616 ± 0.650^{ABab}
Coronal	1.330 ± 0.538^{Ba}	2.454 ± 0.479^{Bbc}	2.003 ± 0.474^{Bb}

Different superscript letters indicate statistically significant differences between groups (*P* < 0.05) (upper case columns, lower case rows).

Table 2 Mean ± standard deviation (SD) of the sealer penetration area (mm2) into the dentinal tubules.

Region	WVC	LC	CB
Apical	4112.62 ± 607.91^{Aa}	5213.22 ± 141.08^{Aa}	7875.91 ± 351.59^{Ab}
Middle	60878.06 ± 1065.35^{Ba}	103969.48 ± 3001.13^{Bb}	75702.06 ± 1820.45^{Bb}
Coronal	102339.44 ± 2782.70^{Ca}	109832.59 ± 4073.16^{Ba}	123552.64 ± 3586.06^{Ca}

Different superscript letters indicate statistically significant differences between groups (*P* < 0.05) (upper case columns, lower case rows).

according to the manufacturer's instructions and then placed in the root canal with gentle pressure for about 5 seconds until it reached the working length. The handles of the obturators were cut at the level of the canal orifice, and the gutta- percha was then condensed using a size 9 posterior Schilder plugger.

In all groups, the gutta-percha was cut 1 mm below the canal level and the cavity was closed with Cavit (ESPE, Seefeld, Germany). After the obturation procedures, periapical radiographs of each tooth (buccolingual and mesiodistal angles) were taken to confirm that there were no voids in the obturation. The samples were then incubated at 37°C in a 100% humidified medium for 2 weeks. Using a low-speed diamond disc (Buehler, Lake Bluff, IL, USA) at 200 rpm under cooling, 1.0 ± 0.1 mm sections were obtained from each sample from the apical (3 mm), middle (resorption area, 7 mm) and coronal (10 mm) regions[20,21]. The sections were polished under water using silicon carbide sandpaper.

Each sample was mounted on a glass slide and examined using CLSM (Nikon Eclipse C1; Nikon Canada, Mississauga, ON, Canada) with ×10 magnification. In cases where the entire canal could not be viewed in an image, images of sections were taken and then combined into a single image using Photoshop (Adobe Systems, San Jose, CA, USA). The maximum penetration depth (mm) and penetration area (mm^2) of the root canal paste in the images obtained were determined using ImageJ software (National Institutes of Health, Bethesda, MD, USA).

Statistical analysis

All statistical analyses were performed using SPSS Statistics version 21.0 (IBM, Armonk, NY, USA). A Shapiro-Wilk test was performed to determine the normal distribution of the data. The data were analysed using a one-way analysis of variance and post-hoc Tukey test. The level of statistical significance was set at *P* < 0.05.

Results

In the CB group, the sealer penetration area was significantly larger in the apical region compared with that in the other groups (*P* < 0.05). In the resorption region, the sealer penetration area was significantly larger in the CB and LC groups compared with that in the WVC group (*P* < 0.05). In the coronal region, there was no significant between-group difference in sealer penetration area (*P* > 0.05).

In all groups, the sealer penetration depth in the apical region was significantly lower than that in the coronal region (*P* < 0.05) and the sealer penetration area in the apical region was significantly lower than that in the coronal region (*P* < 0.05). The sealer penetration depth in the apical region was significantly higher in the CB group as compared with that in the other groups (*P* < 0.05). The sealer penetration depth in the resorption region in the CB and LC groups was significantly higher than that in the WVC group (*P* < 0.05), as shown in Table 1. As illustrated in Table 2, the sealer penetration area increased significantly from the apical to the coronal region in the CB and WVC groups but not in the LC group (*P* < 0.05).

Discussion

In the present study, the effect of different obturation techniques on root canal sealer penetration was evaluated in teeth with IRR. The null hypothesis was rejected as there was a difference between the obturation techniques in terms of penetration of the root canal sealer. In clinical practice, the steam lock phenomenon occurs in the root canal system due to the difference in pressure between the root canal and the periodontal ligament during irrigation and preparation procedures. For this reason, various materials such as alginate, gelatine, saline solution, sponge, agar and polyvinyl siloxane have been used to mimic the resistance of periapical tissues in many in vitro studies[19]. In this study, considering the advantages such as ease of application and low cost, a closed-ended root canal model was created by embedding the teeth in polyvinyl siloxane impression material and simulating in vivo environmental conditions.

In the literature, different imaging methods have been used to evaluate root canal sealer penetration (light microscopy, scanning electron microscopy [SEM], stereomicroscopy and CLSM)[22,23]. A previous study reported that it was difficult to distinguish between sealer and dentine levels when evaluating root canal sealer penetration by light microscopy[24]. In SEM imaging, sample preparation requires multiple processing steps and procedures, such as dehydration, which can damage the sample[22]. Furthermore, the images obtained by SEM are only two-dimensional and only allow evaluation of limited areas of the root canal wall due to high magnification[25,26]. In this study, we used CLSM to evaluate tubular penetration of the root canal seal. CLSM permits histotomographic imaging and examination of the dentine at the subsurface level[25]. An important advantage of CLSM is that there is no need to dehydrate the samples and no artefact formation[27,28]. In addition, using CLSM, the distribution of sealer in dentinal tubules can be visualised at a high magnification and sections can be reconstructed[26,29,30]. To visualise root canal sealer with CLSM, a fluorescent dye is required. In a previous study, rhodamine B dye had no effect on the penetration of resin-based root canal sealer into dentin tubules[25]. Thus, in this study, AH Plus root canal sealer was labelled with rhodamine B dye.

In all the obturation techniques tested in this study, the penetration area and depth of the root canal sealers were greater in the coronal regions than the apical regions. In line with these findings, other studies that used CLSM to investigate root canal sealer penetration reported that it decreased from the coronal to the apical region[31,32]. This decrease in sealer penetration may be due to the decrease in the diameter and number of dentinal tubules in the apical region and increased sclerosis in dentinal tubules[14]. Another explanation may be that more of the smear layer obstructing tubules in root canals is removed in the coronal region than the apical region and that some areas of the latter are covered with cementum-like tissue[33].

In a literature review, we found no previous studies on the effect of different obturation techniques on sealer penetration of dentinal tubules based on a CLSM analysis of teeth with IRR. According to the results of the present study, the root canal sealer penetration area and depth in the apical region were greater in the CB group than the other groups. There was no difference in these parameters in the WVC group versus the LC group. Contrary to these findings, Kok et al[25] found no difference in sealer penetration of dentinal tubules in a CLSM analysis of the apical region in the CB and LC groups. In a CLSM analysis, Marciano et al[34] reported that sealer penetration in both CB and WVC groups in the apical region of mesial canals of mandibular molar teeth with moderate curvature was similar to sealer penetration in an LC group. Keles et al[5] reported no difference between volume percentages and voids of root canal obturation between the LC and WWC groups in the apical region in a microcomputed tomography analysis. Several studies found that the high pressure produced in the apical region increased the penetration of this thin layer of sealer into the root canal walls[33-35]. In the literature, a thinner layer of sealer was needed for CB-based obturation techniques[35]. Based on this idea, the CB obturation technique results in higher sealer penetration in the apical region as compared with that of other obturation techniques.

The present results revealed no difference between the CB and LC groups in terms of sealer penetration in the middle (resorption area) and coronal regions, and the penetration area and sealer depth were smaller in the WVC group as compared with that in the other groups. Similarly, Goldberg et al[35] detected no difference between the LC and CB techniques in terms of obturation efficacy based on stereomicroscopy and radiographic imaging of teeth with IRR. Contrary to the findings of our study, Gençoğlu et al[9] reported that WVC obturation performed in teeth with experimental IRR yielded better results than CB or LC. Marciano et al[34] reported that sealer penetration in the middle and coronal regions of mesial canals of mandibular molar teeth with moderate curvature was higher in an LC group than in a CB group using CLSM analysis. The divergence between the study results may be due to differences in tooth selection, resorption size, sealer selection, preparation size and evaluation methods.

Conclusion

Within the limitations of the present study, tubular penetration of root canal sealer in both the apical and resorption regions in teeth with IRR was higher using the CB technique than the WVC technique.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Zeliha UĞUR AYDIN contributed to the study design, supervision, statistical analysis and literature search; Drs İrem Cansu KARA, Gamze ER KARAOĞLU and Tülin DOĞAN CANKAYA contributed to the experiment, literature search and writing of the manuscript.

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