Original Article

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Evaluation of Filling Quality of Obturation Techniques in Internal Resorption Cavities Created with a Novel Methodology

Yeni Bir Metodoloji ile Oluşturulan İnternal Rezorpsiyon Kavitelerinde Dolum Tekniklerinin Doldurma Kalitesinin Değerlendirilmesi

İdil ÖZDEN, Hesna SAZAK ÖVEÇOĞLU

Marmara University Faculty of Dentistry, Department of Endodontics, İstanbul, Turkey

ABSTRACT

Objective: The aim of this study was to evaluate the impact of filling irregularly bounded internal resorption cavities created by acid demineralization using different filling techniques on the quality of the filling.

Methods: A total of 54 extracted single-rooted teeth were sectioned mesiodistally. Each tooth segment was subjected to 5% nitric acid for 12 hours followed by 8% sodium hypochlorite for 10 minutes. Samples were rinsed with distiled water between the two solutions. The demineralization protocol was renewed every 24 hours and applied for 11 days. At the end of the process, the teeth were reassembled, and randomly divided into six groups, each containing 9 samples:

1. Group 1: AH Plus + Cold Lateral Condensation Technique,
2. Group 2: AH Plus + Thermoplastic Injection Technique,
3. Group 3: T-Endo Bioserra + Cold Lateral Condensation Technique,
4. Group 4: T-Endo Bioserra + Thermoplastic Injection Technique,
5. Group 5: GuttaFlow 2,
6. Group 6: GuttaFlow 2 + Single-Cone Technique.

Filling quality was evaluated by determining the percentage of gutta-percha, sealer, and remaining voids in the resorption cavities through stereomicroscopic examination.

ÖZ

Amaç: Bu çalışmanın amacı; asit demineralizasyonu ile oluşturulan düzensiz sınırlı iç rezorpsiyon kavitelerinin farklı dolum teknikleri ile doldurulmasının, dolum kalitesi üzerindeki etkisini değerlendirmektir.

Yöntemler: Toplamda 54 adet çekilmiş tek köklü diş mesiodistal olarak ikiye ayrıldı. Her iki diş segmentine önce 12 saat 5% nitrik asit; ardından 10 dakika 8% sodyum hipoklorit uygulandı. İki solüsyon arasında örnekler distile su ile yıkanarak temizlendi. Demineralizasyon protokolü 24 saatte bir yenilenerek 11 gün boyunca uygulandı. Sürecin sonunda dişler yeniden bir araya getirildi ve her grupta 9 örnek olacak şekilde rastgele 6 gruba ayrıldı. Gruplar;

Grup 1: AH Plus + Soğuk Lateral Kondenzasyon Tekniği,

Grup 2: AH Plus + Termoplastik Enjeksiyon Tekniği,

Grup 3: T-Endo Bioserra + Soğuk Lateral Kondenzasyon Tekniği,

Grup 4: T-Endo Bioserra + Termoplastik Enjeksiyon Tekniği,

Grup 5: GuttaFlow 2,

Grup 6: GuttaFlow 2+ Tek Kon Tekniği.

Dolum kalitesi, stereomikroskopik inceleme yoluyla rezorpsiyon boşluklarındaki gutaperka, kanal patı ve kalan boşluk miktarlarının belirlenmesiyle değerlendirildi.

Address for Correspondence: İdil ÖZDEN, Marmara University Faculty of Dentistry, Department of Endodontics, İstanbul, Turkey
E-mail: idil.akman94@gmail.com **ORCID ID:** orcid.org/0000-0003-0838-4355

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ABSTRACT

Results: The group filled with AH Plus sealer using the cold lateral condensation technique showed a significantly higher gutta-percha percentage compared to the other groups ($p<0.05$). The GuttaFlow 2 group, applied with the single-cone technique, exhibited the highest gutta-percha percentage (99.01%). When the cold lateral condensation and thermoplastic injection techniques were compared based on sealer contents, no statistically significant difference in gutta-percha percentage in the resorption cavities was observed ($p=0.136$).

Conclusion: Our study demonstrated that none of the obturation techniques used achieved complete filling in the resorption cavities. However, the use of GuttaFlow 2 with the single-cone technique showed superior filling quality, demonstrating excellent adaptation to the root canal walls and ease of application.

Keywords: GuttaFlow 2, internal root resorption, root canal obturation

ÖZ

Bulgular: Soğuk lateral kondensasyon tekniği kullanılarak AH Plus kanal patı ile doldurulan grup, diğer gruplara göre anlamlı olarak daha yüksek pat yüzdesi gösterdi ($p<0,05$). Tek kon tekniğiyle uygulanan GuttaFlow 2 grubu, en yüksek gutaperka yüzdesini sergiledi (%99,01). Soğuk lateral kondenzasyon ve termoplastik enjeksiyon tekniklerin pat içeriklerine göre karşılaştırıldığında, rezorpsiyon boşluklarında pat yüzdesinde istatistiksel olarak anlamlı farklılık gözlenmedi ($p=0,136$).

Sonuç: Çalışmamız, kullanılan hiçbir obtürasyon tekniğinin rezorpsiyon kavitelerinde boşluksuz dolumu başaramadığını ortaya koymuştur. Bununla birlikte, master kon ile uygulanan GuttaFlow 2'nin kullanımı, kök kanal duvarlarına mükemmel uyum ve uygulama kolaylığı göstererek üstün doldurma kalitesi sergilemiştir.

Anahtar Sözcükler: GuttaFlow 2, iç kök rezorpsiyonu, kök kanal dolumu

Introduction

The American Endodontic Society provides a definition of resorption as a condition linked to a physiological or pathological process that results in the loss of dentin, cementum, or bone (1). Resorption involves non-infectious damage caused by the activity of osteoclastic cells, leading to the loss of dental hard tissue (2,3). Root resorptions are categorized as internal or external based on their location on the root surface. Internal root resorption refers to a clinical condition characterized by the gradual destruction of dentin along the walls of the root canal, typically caused by chronic infection or trauma (4,5). Although internal root resorption is rarely identified in clinical settings, histological studies have reported varying incidence rates ranging from 0.01% to 55%, depending on the inflammatory condition of the pulp (6).

Filling the root canal hermetically in cases of internal resorption is an important step in successful treatment (7). However, the irregular structure of the resorption cavities poses a challenge for physicians. Therefore, the efficacy of various techniques and materials in sealing internal root resorption cavities has been evaluated through *ex vivo* study designs.

Obturation of the root canal system is indeed one of the most critical stages of endodontic treatment (8). The primary objective of root canal treatment is to achieve a hermetic seal, thereby preventing apical and coronal leakage. While various methods have been introduced over the years, each method comes with its own set of advantages and disadvantages.

One widely used technique is the cold lateral condensation method, which proves suitable for many clinical conditions. This approach involves filling the gaps between the dentin walls and the gutta-percha by employing auxiliary cones after placing a master gutta-percha cone that corresponds to the canal preparation. However, it may be inadequate in completely filling irregularities within the canal and fails to provide a uniform filling compared to alternative systems (9).

The thermoplastic injection method was initially introduced by Michanowicz and Czonstkowsky in 1984. With this approach, the gutta-percha is heated and softened, and then pressure is applied using specialized devices to place it into the root canal. Injectable gutta-percha has been reported to effectively fill anatomical variations such as intracanal irregularities, internal resorption, C-shaped canals, lateral canals, and branching foramina (10).

Studies have demonstrated that the thermoplastic injection technique is significantly more effective than cold lateral condensation in achieving three-dimensional canal filling (11-13). A recently introduced method, known as the cold-fluid filling technique, is also under evaluation for its potential use in cases of internal resorption. GuttaFlow 2, a cold, flowable, and self-curing root canal filling material, contains polydimethylsiloxane and gutta-percha powder with particle sizes less than 30 μm (14). Due to its reduced viscosity under shear stresses, it exhibits remarkable flow properties. While it can be used with lateral or vertical compaction techniques, it is commonly recommended for single-cone application without mechanical compression (15).

In existing literature, experimental resorption cavities were mechanically created using various types and sizes of burs (15-18). However, in natural resorption cavities, which are formed as a result of clastic cell activity, the demineralized areas exhibit irregular cavity boundaries (19). No study has been found in the literature that evaluates the quality of filling in internal resorption cavities formed through this chemical process.

The aim of this study was to evaluate the effect of different obturation techniques on the quality of filling internal resorption cavities that were created through acid demineralization. Furthermore, the study seeked to assess the extent of resin and bioceramic sealer coverage within these cavities.

This study represents the first investigation in the literature to solely evaluate filling quality based on sealer contents, irrespective of the obturation technique employed.

The null hypothesis of our study is that the relatively newer technique of cold-flow obturation (GuttaFlow 2) may provide more successful filling in terms of internal resorption quality when compared to the traditional cold lateral condensation technique, simple single-cone technique, and thermoplastic injection technique.

Methods

The study obtained ethical approval from the Marmara University Faculty of Dentistry Ethics Committee under decision number: 2022/45, dated 24.02.2022, as human tissues were utilized for the *in vitro* study. After receiving approval from the ethics committee, a total of 54 single-rooted human teeth, extracted for reasons such as caries or periodontal issues, were selected for the study. The inclusion criteria included teeth with single and straight root canals.

Teeth exhibiting complete root development without fractures, cracks, resorption, or anatomical variations were chosen after examination under x25 magnification.

To prepare the specimens, the crowns of each tooth were removed using a diamond bur, resulting in a standardized root length of 12 mm. The teeth were mounted on acrylic blocks (Figure 1). In the next step, the specimens were bisected in the mesiodistal direction using a diamond disc (Buehler Diamond Cut-Off Wheels 114243; Buehler, Lake Bluff, IL) attached to a chainsaw (IsoMet Low Speed Saw; Buehler) with water cooling. Metal discs, measuring 2 mm in width and 2 mm in height, were placed in the middle third of the root length in both segments of the tooth. These discs were securely fixed with the aid of a gingival barrier (Gingiva Shield VLC, PrevestDenPro, India) and the tightness was ensured (Figure 2).

The demineralization protocol for creating the resorption cavity spanned a duration of 11 days. The protocol involved three steps: first, the application of a 5% nitric acid solution for 12 hours; second, the exposure to an 8% sodium hypochlorite (NaOCl) solution for 10 minutes; and finally, another 12 hour application of a 5% nitric acid solution (19). Distilled water was used for rinsing between each solution, and throughout the entire duration, the samples were stored at a temperature of -1 °C (+/-3 °C) (Figure 3). At the conclusion of this period, the metal rings were removed from the root surface, and any residues were thoroughly cleaned. Liquid adhesive was applied to the acrylic surfaces, allowing the parts to be assembled in such a way that the resorption areas on both root surfaces were opposite each other. This prepared the samples for root canal preparation.

The working length of the root canals was determined by using a no.15 K-file (Mani, Japan), and 0.5 mm was subtracted from the length visible at the apical foramen. For cleaning and shaping the root canals, rotary nickel-titanium instruments (ProTaper, Dentsply Maillefer) were employed, with an X2 file attached to a torque-controlled reduction handpiece (X-Smart, Dentsply Maillefer). Irrigation was performed between each instrument using 2.5 mL of 2.5% NaOCl. Following the completion of the preparation, the root canals were rinsed with 5 mL of 2.5% NaOCl for 1 minute. The samples were randomly divided into 6 groups, with 9 samples in each group (Table 1). The Calamus Dual Obturation System (Dentsply Maillefer, Ballaigues, Switzerland) was used to the thermoplastic injection technique.

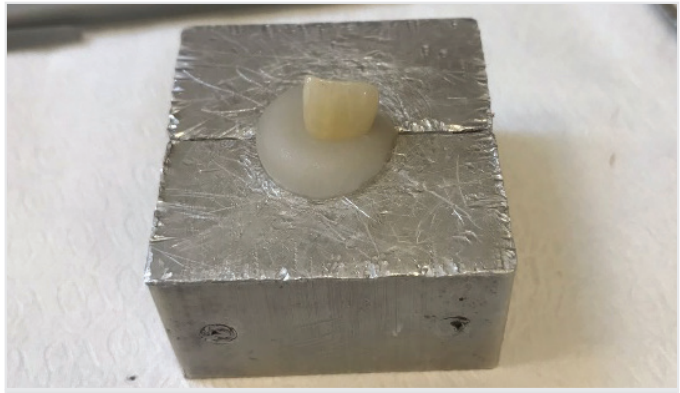

Figure 1. Samples preparation

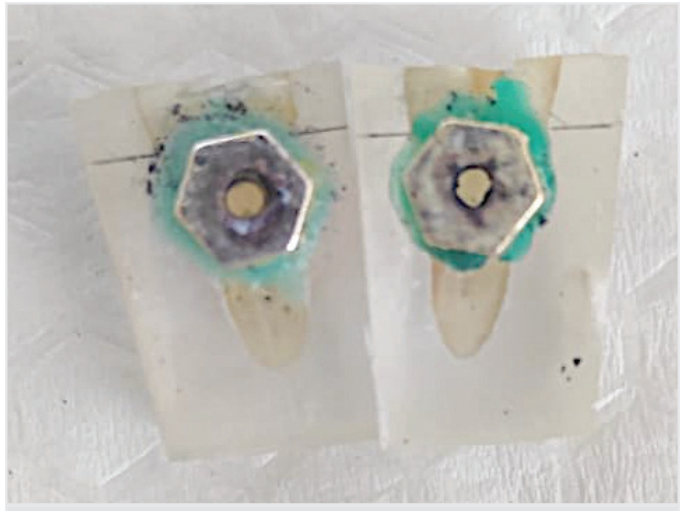

Figure 2. Preparation of resorption cavities

Figure 3. Resorption cavities

After storing the samples at room temperature for 7 days, a 7 mm section was obtained from each tooth for analysis. The root sections were then examined under a Leica MZ 7.5 stereomicroscope (Leica, Germany) at 25x magnification. Microscope images were captured and loaded into computer-based image analysis software (ImageJ and NIH Image Software; National Institutes of Health, Bethesda, Md) (Figure 4). A software program was utilized to calculate the percentages of sealer, gutta-percha, and voids present in the root sections of each group (Figure 5).

Statistical Analysis

Statistical analyses were performed using the SPSS28 software (IBM Corp., Armork, NY,USA). The Kruskal-Wallis and Mann-Whitney U tests were utilized to determine any significant differences between the groups. A p value below 0.05 was considered statistically significant.

Results

The Kruskal-Wallis test was utilized to examine the differences between the groups. The results of the Kruskal-Wallis test indicated a statistically significant difference in the percentages of gutta-percha and sealer within the resorption cavities ($p<0.05$). However, no significant difference was found between the groups in terms of the percentage of voids present in the cavities ($p>0.05$) (Table 2). Table 3 and Table 4 present the results of the study, comparing the percentages of gutta-percha and sealer within the resorption cavities among the different groups.

Further analysis of the stereomicroscope images revealed that group 1 had a significantly higher percentage of sealer compared to the other groups ($p<0.05$). Group 6 exhibited the highest percentage of gutta-percha. When comparing the first four groups with each other in terms of sealer content, no statistically significant difference was observed in the percentage of sealer within the resorption cavities ($p>0.05$).

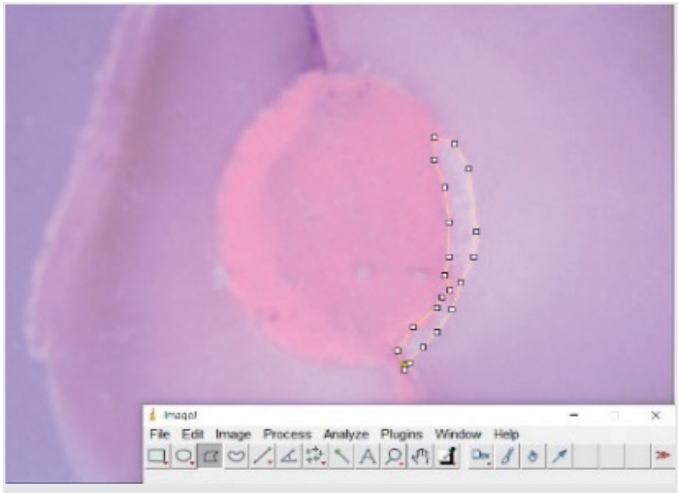

Figure 4. ImageJ data

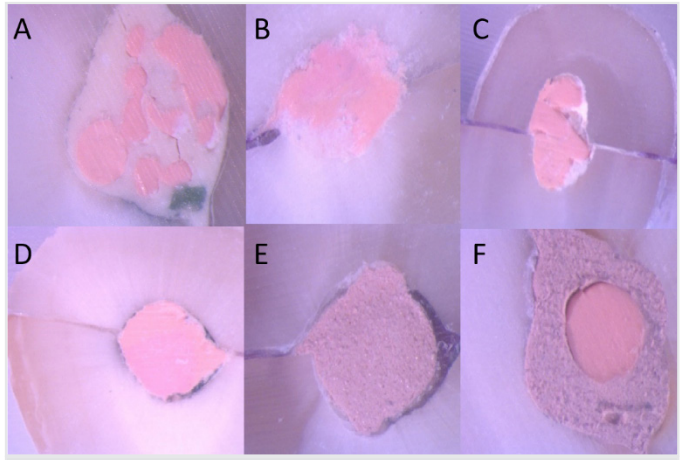

Figure 5. Stereomicroscopic images of the samples (25x magnification)

5A: Group 1 (AH Plus Sealer + Cold Lateral Condensation Technique), **5B:** Group 2 (AH Plus Sealer + Thermoplastic Injection Technique), **5C:** Group 3 (T-Endo Bioserra Sealer + Cold Lateral Condensation Technique), **5D:** Group 4 (T-Endo Bioserra Sealer + Thermoplastic Injection Technique), **5E:** Group 5 (GuttaFlow 2), **5F:** Group 6 (GuttaFlow 2 + Single Cone Technique)

Table 1. Groups of the study

	Obturation technique	Sealer
Group 1	Cold Lateral Condensation	AH Plus
Group 2	Thermoplastic Injection Technique	AH Plus
Group 3	Cold Lateral Condensation	T-Endo Bioserra
Group 4	Thermoplastic Injection Technique	T-Endo Bioserra
Group 5	Gutta Flow 2	Gutta Flow 2
Group 6	Single Cone Technique	Gutta Flow 2

Table 2. The percentages of gutta-percha, sealer and void in the cavities

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	p
Gutta Percha	47.00	87.22	64.98	79.92	93.06	96.57	<0.001
Sealer	40.00	7.76	23.20	18.45	-	-	<0.001
Void	5.57	1.99	8.23	4.91	6.94	3.43	0.136

Table 3. Comparisons of obturation percentages of resorption cavities with gutta-percha among groups

Groups	p
Group 1-Group 3	0.338
Group 1-Group 4	0.045
Group 1-Group 2	*0.002*
Group 1-Group 5	<0.001
Group 1-Group 6	<0.001
Group 3-Group 4	0.294
Group 3-Group 2	0.35
Group 3-Group 5	<0.001
Group 3-Group 6	<0.001
Group 4-Group 2	0.287
Group 4-Group 5	0.012
Group 4-Group 6	0.001
Group 2-Group 5	0.150
Group 2-Group 6	0.31
Group 5-Group 6	0.472

Table 4. Comparisons of obturation percentages of resorption cavities with sealer among groups

Groups	p
Group 2-Group 4	0.277
Group 2-Group 3	0.018
Group 2-Group 1	<0.001
Group 4-Group 3	0.245
Group 4-Group 1	0.002
Group 3-Group 1	0.049

Discussion

The success of root canal treatment can be negatively affected in the presence of voids that provide a space for microbial colonization within the cavity. If the resorption cavity is not completely filled, these voids can serve as focal points for microbial colonization, leading to contamination and microleakage, which can have a detrimental effect on treatment success (20). In our study, we evaluated the percentage of area covered by resin and bioceramic-based sealers after filling the cavities using two different sealers in cases involving irregular cavities such as internal resorption.

In our study, the experimental resorption cavities were positioned in the middle one-third of the roots of maxillary central incisors, considering the higher prevalence of internal root resorption in this region and its frequent occurrence in the middle and apical thirds of the root (21,22).

Unlike previous *in vitro* studies (15-18), our study followed a methodology similar to the one conducted by da Silveira et al. (19) in 2014. We created irregular demineralized areas using nitric acid and NaOCl, aiming to simulate actual internal resorption cavities more accurately. These chemically formed cavities were designed to closely resemble the characteristics of real internal resorption cavities. For filling the artificial internal root resorption cavities in our study, we employed three preferred obturation techniques. The first technique used was the cold lateral condensation technique, which was the most commonly used and widely practiced technique in the clinic (23,24). The second technique chosen was Calamus Dual Obturation System, a system that utilized injectable thermoplasticized gutta-percha. Studies have indicated that the thermoplastic injection technique is significantly superior to cold lateral condensation, providing better three-dimensional canal filling (25-27). In our study, GuttaFlow 2 (Micromega, Coltene Whaledent, USA), a flowable filling material at room temperature, was utilized. It was evaluated in two groups: one group involved the use of a master cone, while the other group did not use a master cone.

For the evaluation of the obtained images, stereomicroscope analysis was chosen in our study. This method was preferred to obtain a clearer view of the surface, which would then be transferred to the image analysis software for further analysis.The advantages of using a stereomicroscope include not requiring any pre-processing of the samples, providing a three-dimensional view, and eliminating human errors that may occur during the interpretation of parameters (24). However, a disadvantage of the stereomicroscope is that it examines and evaluates only a certain cross-sectional area of the resorption cavity, leaving other areas unassessed (25). The necessity of obtaining sections from the samples is also seen as a disadvantage due to the potential irreversible damage it may cause (26).

For image analysis in our study, we used ImageJ, a Java-based image processing and analysis program. ImageJ provides the capability to calculate area and pixel value statistics for user-defined selections. Additionally, it enables measurements of distances and angles. It is preferred for its support of standard image processing functions and the ability to perform geometric transformations such as measurements (27).

The null hypothesis was accepted in our study. None of the filling techniques used completely filled the resorption cavities. But when evaluating the percentage of cavity filling with sealer or gutta-percha, the group filled with AH Plus sealer using the cold lateral condensation technique had the highest sealer percentage (40.40%), while the group treated with GuttaFlow 2 using the master cone technique had the highest gutta-percha percentage (96.57%).

When the percentages of void areas in the experimental groups were ranked according to medians, the highest percentage of voids was observed in the group filled with T-endo Bioserra sealer (Dentac, Istanbul, Turkey) using the cold lateral condensation technique (8.23%), while the lowest percentage of voids was found in the group filled with AH Plus sealer (Dentsply De Trey Gmbh, Konstanz, Germany) using the thermoplastic injection technique (1.99%). However, the difference observed between the groups was not statistically significant. These findings align with the existing literature on the subject (28,29).

Most studies in the literature have consistently demonstrated the advantages of the thermoplastic injection technique in

effectively filling internal resorption cavities. These studies have reported that the root canal filling should ideally contain a higher proportion of gutta-percha and a lower amount of sealer. Gençoğlu et al. (13) compared various filling techniques for the filling of mechanically created internal resorption cavities in their study. The researchers found that Obtura II (Obtura Spartan, Fenton, MO) with the thermoplastic injection technique filled the resorptive area significantly better than the cold lateral condensation technique using Obtura II. Similarly, *in vitro* studies with similar methodologies comparing different filling techniques for filling internal resorption cavities have concluded that the thermoplastic injection method creates higher quality fillings compared to cold lateral condensation (8,15,18). Additionally, the literature has documented successful outcomes associated with the utilization of warm obturation techniques for the treatment of teeth exhibiting internal resorption (30,31). The evaluation of gutta-percha amounts in the resorption cavities in our study revealed that the group with the highest gutta-percha filling was the one treated with GuttaFlow 2 and the simple single-cone technique. Our results are consistent with the findings of Naseri et al. (28), Gençoğlu et al. (13), and Goldberg et al. (22) in the literature. The group treated with the thermoplastic injection technique using T-endo Bioserra sealer showed a significantly lower percentage of gutta-percha filling within the cavities compared to the group treated with GuttaFlow 2 using the master cone technique. This finding differs from some studies in the literature. In a study by Anantula and Ganta (24) these two techniques were compared and it was reported that the thermoplastic injection provided a more compatible filling to the canal walls and resulted in fewer voids compared to the groups treated with GuttaFlow. Similarly, in a study by Kumar et al. (32), the filling capacities of GuttaFlow 2, thermoplastic injection technique, and cold lateral condensation technique were compared. The researchers found that the thermoplastic injection technique provided significantly better filling than the other groups. We believe that the difference between the results of our study and the results of other studies in the literature may be due to differences in methodology. While previous studies evaluated the adaptation to the canal walls of mechanically created cavities, our study evaluated irregular demineralized areas created to simulate patients encountered in clinical practice.

In another study, researchers compared GuttaFlow 2 with the cold lateral condensation technique to assess apical microleakage. The findings of the study revealed that when GuttaFlow 2 was applied with the master cone technique, it resulted in the least amount of dye penetration in comparison to the cold lateral condensation technique (33).

Study Limitations

Our study had limitations including its *in vitro* design, minimal loss of tooth structure due to sectioning of tooth segments, and filling of created voids with paste. However, this study was the first to evaluate the filling of root canals in internal resorption cavities created by acid demineralization using GuttaFlow 2. We believe that our results will contribute to the literature and provide insights for further studies in this area.

Conclusion

In conclusion, our study revealed that none of the obturation techniques used in the treatment of resorption cavities were able to completely fill the defects. However, the GuttaFlow 2 applied with the master cone demonstrated superior filling quality, offering good adaptation to the root canal walls and ease of use. Significantly, this study is the inaugural examination in the literature to exclusively evaluate filling quality based on the resorption cavity content, irrespective of the obturation technique employed. Therefore, further investigations involving *in vivo* and long-term assessments are necessary.

Ethics

Ethics Committee Approval: The study obtained ethical approval from the Marmara University Faculty of Dentistry Ethics Committee under decision number: 2022/45, dated 24.02.2022, as human tissues were utilized for the *in vitro* study.

Informed Consent: *In vitro* study.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: İ.Ö., H.S.Ö., Design: İ.Ö., H.S.Ö., Data Collection or Processing: İ.Ö., H.S.Ö., Analysis or Interpretation: İ.Ö., Literature Search: İ.Ö., Writing: İ.Ö., H.S.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

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