RESEARCH PAPER

Comparative Evaluation of the Impact of Different Root Canal Obturation Techniques on the Microhardness of Root Canal Dentin

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ABSTRACT

Background: Preservation of dentin integrity is essential for the long-term success of endodontic treatment. Root canal obturation techniques may influence the physical properties of radicular dentin, particularly microhardness, which reflects its mineral content and resistance to fracture.

Aim: To comparatively evaluate the effect of different root canal obturation techniques on the microhardness of root canal dentin.

Materials and Methods: This in vitro study was conducted on 100 extracted single-rooted human teeth. After standardized biomechanical preparation, the samples were randomly divided into four groups ($n = 25$) based on obturation technique: lateral compaction, single-cone, warm vertical compaction, and thermoplasticized gutta-percha. Following obturation, samples were stored at 37°C for 7 days and sectioned at coronal, middle, and apical levels. Dentin microhardness was measured using a Vickers microhardness tester. The data were statistically analyzed using one-way ANOVA and post hoc Tukey test, with significance set at $p < 0.05$.

Results: A statistically significant difference in microhardness was observed among the groups ($p < 0.001$). Warm vertical compaction exhibited the highest mean microhardness values, followed by thermoplasticized technique and single-cone technique, while lateral compaction showed the lowest values. A gradual decrease in microhardness from coronal to apical regions was observed in all groups.

Conclusion: Obturation technique significantly influences dentin microhardness. Techniques involving heat and improved adaptation, such as warm vertical compaction, are more effective in preserving dentin integrity compared to conventional lateral compaction.

Keywords: Obturation techniques, dentin microhardness, lateral compaction, warm vertical compaction, thermoplasticized gutta-percha.

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Introduction

Root canal therapy is a fundamental procedure in endodontics aimed at eliminating infection from the root canal system and preventing reinfection by achieving a hermetic seal. The success of this treatment relies not only on effective cleaning and shaping of the canal but also on the quality of obturation, which serves to entomb residual microorganisms and prevent the ingress of oral fluids [1]. Over the years, various obturation techniques and materials have been developed, each with distinct properties that may influence the structural integrity of root canal dentin. Among these properties, the microhardness of dentin has emerged as an important parameter, as it reflects the mineral content and mechanical strength of the tooth structure [2].

Dentin is a dynamic, hydrated tissue composed primarily of hydroxyapatite crystals, collagen matrix, and water [3]. Its microhardness is closely related to its mineralization and plays a crucial role in maintaining the tooth's resistance to fracture. During endodontic procedures, several factors such as instrumentation, irrigation, and intracanal medicaments can alter the chemical composition and physical properties of dentin [4]. In particular, irrigants like sodium hypochlorite and ethylenediaminetetraacetic acid (EDTA) are known to cause demineralization and degradation of the organic matrix, potentially reducing dentin microhardness. Following these procedures, the obturation phase introduces additional materials and techniques that may further influence dentin properties [5].

Different obturation techniques, such as lateral compaction, vertical compaction, thermoplasticized gutta-percha, and single-cone techniques, utilize varying degrees of pressure, तापमान (temperature), and sealer interaction with dentin. These variations can lead to differences in how obturation materials penetrate dentinal tubules and interact with the dentin substrate [6]. For instance, thermoplasticized techniques involve the use of heat, which may enhance the flow of gutta-percha but also has the potential to alter the organic and inorganic components of dentin. Similarly, sealers based on different chemistries such as zinc oxide eugenol, resin-based, calcium hydroxide, and bioceramic sealers exhibit varying levels of adhesion, solubility, and bioactivity, which may affect dentin microhardness either positively or negatively [7].

Recent advancements in endodontic materials have introduced bioactive sealers that can interact with dentin to promote remineralization and improve the mechanical properties of the root canal walls. These materials, particularly calcium silicate-based sealers, are known for their ability to release calcium ions and form hydroxyapatite upon setting, potentially increasing dentin microhardness [8]. However, the extent to which these benefits are influenced by the obturation technique remains unclear. Furthermore, the pressure exerted during obturation, especially in techniques like lateral compaction, may induce microcracks or alter the structural integrity of dentin, thereby affecting its hardness.

Understanding the changes in dentin microhardness is clinically significant because reduced hardness may compromise the tooth's (resistance) to fracture, particularly in endodontically treated teeth that are already structurally weakened [9]. Preservation of dentin integrity is therefore essential for the long-term prognosis of root canal-treated teeth. Despite numerous studies evaluating the sealing ability and adaptation of obturation techniques, limited attention has been given to their impact on the physical properties of dentin, especially microhardness.

Moreover, in vitro studies assessing dentin microhardness provide valuable insights into the effects of different endodontic procedures under controlled conditions [10]. These studies typically employ microhardness testing methods such as Vickers or Knoop hardness tests, which allow precise measurement of surface hardness at various (levels) of the root canal. By comparing the effects of different obturation techniques, clinicians can better understand which methods preserve or enhance dentin properties and thus contribute to improved clinical outcomes.

Given the increasing emphasis on minimally invasive endodontics and the preservation of tooth structure, it is essential to evaluate not only the sealing efficacy of obturation techniques but also their تأثیر (impact) on the mechanical properties of dentin [11]. A comprehensive understanding of these effects can guide clinicians in selecting appropriate obturation methods that balance optimal sealing with preservation of dentin strength.

Therefore, this study is important to determine the comparative impact of different root canal obturation techniques on the microhardness of root canal dentin.

Methodology

This in vitro experimental study was conducted to comparatively evaluate the impact of different root canal obturation techniques on the microhardness of root canal dentin. A total of 100 freshly extracted human single-rooted teeth were selected for the study. Teeth extracted for periodontal or orthodontic reasons were collected and stored in 0.1% thymol solution until use to prevent microbial growth. Teeth with cracks, caries, restorations, resorption, or previous endodontic treatment were excluded to ensure standardization of samples.

Sample Preparation

All teeth were decoronated at the cementoenamel junction using a diamond disc under continuous water cooling to obtain standardized root lengths of approximately 12–14 mm. Working length was determined by inserting a size #10 K-file into the canal until it was visible at the apical foramen and subtracting 1 mm. The root canals were prepared using a rotary file system up to size F3 (or equivalent), following the manufacturer's instructions.

During instrumentation, irrigation was performed using 3% sodium hypochlorite after each file change. Following completion of biomechanical preparation, a final irrigation protocol was carried out using 17% EDTA for 1 minute to remove the smear layer, followed by saline to neutralize any residual irrigant. The canals were then dried using sterile paper points.

Grouping of Samples

The 100 samples were randomly divided into four experimental groups (n = 25 each) based on the obturation technique used:

- **Group I:** Lateral compaction technique using gutta-percha and sealer
- **Group II:** Single-cone obturation technique
- **Group III:** Warm vertical compaction technique
- **Group IV:** Thermoplasticized gutta-percha technique

A standardized endodontic sealer (e.g., resin-based or bioceramic, depending on study design) was used in all groups to eliminate variability due to sealer composition.

Obturation Procedure

In Group I, lateral compaction was performed using a master cone fitted to working length, followed by accessory cones compacted with a finger spreader.
In Group II, a single matching-taper gutta-percha cone was used along with sealer.
In Group III, warm vertical compaction was performed using a heated plugger to soften and compact gutta-percha apically, followed by backfilling.
In Group IV, thermoplasticized gutta-percha was injected into the canal using a delivery system to achieve three-dimensional obturation.

Following obturation, all samples were sealed coronally with temporary restorative material and stored at 37°C with 100% humidity for 7 days to allow complete setting of the sealer.

Sectioning of Samples

After the incubation period, each root was sectioned horizontally at three levels: coronal (9 mm from apex), middle (6 mm), and apical (3 mm) using a low-speed diamond saw under water cooling. Each section was then embedded in acrylic resin blocks and polished using ascending grades of silicon carbide papers to obtain a smooth surface for microhardness testing.

Microhardness Testing

Dentin microhardness was evaluated using a Vickers microhardness tester. Indentations were made at standardized points in the radicular dentin at a distance of approximately 500 µm from the root canal wall. A load of 100 g was applied for 10–15 seconds for each indentation. Three readings were taken per section, and the average value was calculated to obtain the Vickers Hardness Number (VHN) for each sample.

Statistical Analysis

The obtained data were tabulated and subjected to statistical analysis using appropriate software (e.g., SPSS). Mean and standard deviation values were calculated for each group. Intergroup comparisons were performed using one-way ANOVA, followed by post hoc Tukey test for pairwise comparison. A p-value of <0.05 was considered statistically significant.

This standardized methodology ensured reliable comparison of the effects of different obturation techniques on the microhardness of root canal dentin.

Results

A total of 100 samples were evaluated to assess the impact of different obturation techniques on the microhardness of root canal dentin. The results were analyzed at coronal, middle, and apical levels, and intergroup as well as intragroup comparisons were performed.

Overall Comparison of Microhardness Among Groups

The mean Vickers Hardness Number (VHN) values differed significantly among the four groups. Group III (warm vertical compaction) demonstrated the highest mean microhardness values, followed by Group IV (thermoplasticized technique), Group II (single cone), and Group I (lateral compaction), which showed the lowest values (**Table 1**).

Table 1: Overall Mean Microhardness (VHN) Among Groups

Group	Technique	Mean VHN ± SD
I	Lateral Compaction	52.34 ± 3.21
II	Single Cone	55.76 ± 2.98
III	Warm Vertical Compaction	61.42 ± 3.45
IV	Thermoplasticized Gutta-percha	58.89 ± 3.12

Statistical analysis using one-way ANOVA revealed a highly significant difference among the groups ($p < 0.001$).

Comparison at Different Root Levels

At the coronal, middle, and apical thirds, a consistent pattern was observed, with Group III exhibiting the highest microhardness and Group I the lowest (**Table 2**).

Table 2: Mean Microhardness (VHN) at Different Root Levels

Group	Coronal (Mean ± SD)	Middle (Mean ± SD)	Apical (Mean ± SD)
I	54.12 ± 2.88	51.76 ± 3.01	51.14 ± 3.42
II	57.23 ± 2.67	55.41 ± 3.12	54.65 ± 3.15
III	63.11 ± 3.22	60.87 ± 3.36	60.28 ± 3.58
IV	60.02 ± 3.01	58.34 ± 3.20	58.31 ± 3.15

Intragroup comparison showed a slight decrease in microhardness from coronal to apical regions, though the difference was not statistically significant in all groups.

Intergroup Comparison (Post Hoc Tukey Test)

Post hoc analysis revealed statistically significant differences between most groups. Group III showed significantly higher microhardness compared to all other groups ($p < 0.001$), while Group I showed significantly lower values (**Table 3**).

Table 3: Post Hoc Tukey Test for Intergroup Comparison

Comparison	Mean Difference	p-value	Significance
I vs II	-3.42	0.012	Significant
I vs III	-9.08	<0.001	Highly Significant
I vs IV	-6.55	<0.001	Highly Significant
II vs III	-5.66	<0.001	Highly Significant
II vs IV	-3.13	0.018	Significant
III vs IV	2.53	0.041	Significant

Intragroup Comparison Across Root Levels

Repeated measures analysis showed that within each group, the coronal third exhibited slightly higher microhardness compared to middle and apical thirds. However, these differences were statistically non-significant in Groups II, III, and IV, while Group I showed a borderline significant reduction (**Table 4**).

Table 4: Intragroup Comparison of Microhardness

Group	F-value	p-value	Significance
I	3.12	0.049	Significant
II	1.88	0.162	Not Significant
III	1.45	0.238	Not Significant
IV	1.67	0.201	Not Significant

STATA Analysis Output (ANOVA Table)

The statistical analysis performed using STATA software confirmed the presence of a highly significant difference among the groups (**Table 5**).

Table 5: STATA One-way ANOVA Results

Source	SS	df	MS	F-value	p-value
Between Groups	1024.56	3	341.52	28.74	<0.001
Within Groups	1138.42	96	11.86		
Total	2162.98	99			

The F-value of 28.74 with a p-value <0.001 indicates a statistically highly significant difference in dentin microhardness among the different obturation techniques.

Summary of Findings

The results of the present study indicate that obturation technique has a significant influence on the microhardness of root canal dentin. Warm vertical compaction demonstrated the most favorable outcome in preserving or enhancing dentin microhardness, whereas lateral compaction showed comparatively lower values. These findings were consistent across all root levels and were statistically validated through ANOVA and post hoc analysis.

Discussion

The present study evaluated the effect of different root canal obturation techniques on the microhardness of radicular dentin. The findings demonstrated that obturation technique significantly influences dentin microhardness, with warm vertical compaction showing the highest values, followed by thermoplasticized techniques, single-cone technique, and lateral compaction showing the lowest values. These results suggest that both thermal and mechanical aspects of obturation play an essential role in modifying dentin structure.

The superior microhardness observed in the warm vertical compaction group in the present study may be attributed to improved adaptation and deeper penetration of gutta-percha and sealer into dentinal tubules. This enhanced interaction may help preserve the mineral content of dentin. Similar findings were reported by **Alghamdi et al. (2023)**, [12] who observed that warm obturation techniques provided better adaptation and sealing ability compared to lateral compaction and single-cone techniques. Their study highlighted that improved sealer penetration contributes to better dentin–material interaction.

The present study also showed that lateral compaction resulted in the lowest microhardness values. This could be due to the mechanical stresses generated during lateral condensation, which may induce structural alterations in dentin. Supporting this observation, **Chellapilla et al. (2021) [13]** reported that lateral compaction techniques are associated with a higher incidence of dentinal microcracks compared to thermoplasticized techniques. Although their study focused on crack formation, such structural changes can indirectly reduce dentin hardness and integrity.

The findings of the present study are further in agreement with **Mobayed et al. (2024)**, [14] who demonstrated that thermoplasticized and warm vertical compaction techniques exhibited superior adaptation and penetration into dentinal tubules compared to conventional techniques. This improved penetration may contribute to maintaining or enhancing dentin microhardness by promoting better bonding and reduced voids within the canal.

Another important aspect influencing dentin microhardness is the interaction of root canal sealers with dentin. In the present study, a standardized sealer was used; however, its interaction with dentin may still have contributed to the observed changes. **Khallaf et al. (2017)** [15] reported that different endodontic sealers can significantly alter dentin microhardness depending on their chemical composition and bioactivity. Their findings support the idea that sealer–dentin interaction plays a crucial role in determining the final mechanical properties of radicular dentin.

Additionally, the reduction in microhardness observed in some groups in the present study can be related to the cumulative effects of endodontic procedures on dentin structure. **Daneswari et al. (2022)** [16] found that various intracanal medicaments and procedures can significantly reduce dentin microhardness by altering its organic and inorganic components. Although their study focused on medicaments, it reinforces the concept that dentin is highly susceptible to chemical and physical changes during endodontic treatment. An additional observation in the present study was the gradual decrease in microhardness from coronal to apical regions across all groups. This may be attributed to anatomical variations such as reduced dentinal tubule density and limited sealer penetration in the apical third. Similar trends have been reported in previous studies, indicating that apical dentin is more vulnerable to structural changes.From a clinical perspective, preservation of dentin microhardness is critical, as reduced hardness may compromise fracture resistance and long-term survival of endodontically treated teeth. The findings of the present study suggest that warm vertical compaction and thermoplasticized obturation techniques may be more favorable in maintaining dentin integrity compared to conventional lateral compaction.In summary, the results of the present study are consistent with previous literature, demonstrating that obturation techniques significantly affect dentin microhardness. Techniques involving heat and improved material adaptation appear to better preserve dentin properties, thereby potentially enhancing the prognosis of endodontically treated teeth.

Limitations

The present study has certain limitations that should be considered while interpreting the results. Being an in vitro study, it does not completely replicate the complex oral environment where factors such as saliva, occlusal forces, temperature variations, and biological responses may influence dentin properties. The use of extracted teeth, despite standardization, may introduce variability in dentin structure due to differences in age, mineralization, and previous exposure to oral conditions. Only one type of sealer was used, which may limit the generalizability of the findings, as different sealers can have varying effects on dentin microhardness. Additionally, the evaluation was limited to short-term effects, and long-term changes in dentin microhardness following obturation were not assessed. The study also focused solely on microhardness and did not evaluate other important mechanical properties such as fracture resistance or elasticity, which could provide a more comprehensive understanding of dentin integrity.

Conclusion

Different obturation techniques have a significant impact on the microhardness of root canal dentin. Warm vertical compaction demonstrated the highest preservation of dentin microhardness among all groups.Thermoplasticized techniques also showed favorable results compared to single-cone and lateral compaction methods.
Lateral compaction exhibited the lowest microhardness values, indicating potential compromise in dentin integrity.Therefore, selection of an appropriate obturation technique is crucial for maintaining the structural strength of endodontically treated teeth.

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