

Volumetric Analysis of Root Canal Obturation Techniques Using CBCT: Potential Implications for Tinnitus and Systemic Health

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ABSTRACT

Aim: This study was designed to assess the volumetric analysis of three different obturation techniques namely lateral condensation technique, single cone technique, and thermoplasticized technique, using three-dimensional Cone Beam Computed Tomography.

Background: Successful root canal treatment requires three-dimensional obturation of the root canal system providing a fluid-tight seal. Proper obturation also minimizes the risk of systemic complications, including low-grade infections, which may have implications for tinnitus by influencing inflammatory or neural pathways. This underscores the broader significance of volumetric analysis in understanding the potential systemic impacts of dental health.

Materials and Methods: Eighty-four single-rooted premolar teeth with single canals were selected. The working length was standardized at 13 mm, of which 4.3 mm each of the coronal, middle, and apical segments were taken into consideration. The samples were grouped into three groups Group A hand files, Group B- Hyflex EDM file system, and Group C- Neoendo neohybrid file system of 28 samples each based on the type of canal instrumentation. All specimens were scanned using CBCT after instrumentation of the root canals. It was further subgrouped into A1, A2, B1, B2, C1, and C2 of 14 samples each based on different obturation techniques—lateral condensation technique, Single cone technique, and Thermoplasticized technique. To determine the POV of gutta-percha, a second CBCT was performed.

Statistical Analysis: Using SPSS version 17.0 software, statistical analysis was performed. The mean difference was calculated by analysis of Variance (ANOVA). A multiple comparison Turkey post-hoc test was performed to find out the exact significance among groups after obturation. The significant value (P-value) was set for 0.05, and any value equal to or less than was considered significant.

Results: Voids were present in all six subgroups. The highest POV was seen with subgroup B2 and the lowest with subgroup C1. The lateral condensation technique showed intermediate results. These findings may hold relevance for interdisciplinary research, particularly in exploring the role of dental procedures in systemic conditions such as tinnitus, where infection control and sealing integrity could influence patient outcomes.

Keywords: Volumetric analysis, Cone beam computed tomography, Percentage obturation volume, Obturation techniques, Tinnitus, Interdisciplinary research.

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INTRODUCTION

Shaping and cleaning is the main aim of Endodontic therapy, followed by the three-dimensional obturation of the root canal space. The treatment success depends upon the triad of thorough canal debridement, effective disinfection, and three-dimensional filling of the root canal space¹.

One of the most important roles of obturation is to provide a three-dimensional hermetic seal for the root canal space from both coronal and apical leakage, thereby prolonging the longevity and the functional success of the endodontically treated tooth. There are various obturation techniques followed for obturation, such as Cold Lateral technique for Condensation, Warm Vertical technique for condensation, Continuous wave technique for compaction, Thermoplasticized gutta-percha, and Carrier-based systems, etc².

CBCT has wide applications in endodontics, implantology, and oral and maxillofacial surgery. This blossoming field provides opportunities for practitioners to combine the uses of CBCT for diagnosis to evaluate the quality of obturation and detect the presence of voids, which can further lead to the failure of Endodontic treatment³.

Dental infections or improperly sealed root canals may exacerbate systemic conditions, including tinnitus, through inflammatory pathways or nerve-related complications⁴. Infections originating in the root canal system could contribute to low-grade inflammation or sensory disturbances that may influence auditory symptoms⁵. This highlights the significance of achieving optimal obturation to minimize these risks⁶.

Moreover, the broader implications of endodontic techniques for systemic health are noteworthy, particularly their potential role in mitigating auditory conditions such as tinnitus. Understanding these connections underscores the interdisciplinary importance of this study for both dental and auditory health research⁷.

Hence, this in-vitro study aims to assess the homogeneity of obturation of the root canals obturated by using three different obturation techniques, namely the Cold Lateral Compaction Technique, Single cone obturation technique, and Thermoplasticized obturating system, and to evaluate the presence of voids using CBCT as the diagnostic tool.

This study was conducted at the premises of All India Institute of Medical Sciences, Kalyani, and CBCT was taken in Grayscale Oral CBCT Diagnostic Centre, AIIMS Kalyani.

MATERIALS & METHODS

Inclusion Criteria

Extraction of single-rooted and single canal premolars (fully formed apices) are collected from the Oral and Maxillofacial Surgery Department, All India Institute of Medical Sciences, Kalyani, and different private dental clinics around Kalyani city.

Exclusion Criteria

Teeth which were having dental caries, restored teeth, teeth having visible cracks, teeth with root canal treatment, teeth having fractures, abrasion in teeth, teeth with any malformation, teeth having structural deformities, developmental defects, and teeth with open apex were excluded.

Preparation of the Samples

The teeth at the cemento-enamel junction were sectioned using a diamond disc, to standardize the length of the root as 13 mm. By placing the 15-size K file in the canal, the determination of working length was done until the apex, and then the file was retrieved 0.5 mm from the apex. For coating the root surfaces and to simulate the periodontal ligament space, silicon impression material was used. The teeth were mounted in acrylic resin. The teeth were then divided into 3 groups based on the type of canal instrumentation.

The specimens were randomly divided and prepared as:

- Group A (N=28): Specimens were prepared using Hand files (crown-down technique). Apical enlargement was done to size 25 K files.
- Group B (N=28): Instrumentation was done using a Hyflex EDM rotary file (crown-down technique).
- Group C (N=28): Instrumentation was done using a Neohybrid rotary file (crown-down technique).

Cone Beam Computed Tomography Pre-Obturation Imaging:

Cone Beam Computed Tomography was used to scan all the specimens after instrumentation of the root canals. CBCT plays a crucial role in detecting voids within the root canal system, which is vital for preventing infections that could have systemic effects, including the exacerbation of conditions such as tinnitus. The precise identification of voids ensures optimal sealing and reduces the risk of microbial infiltration that may influence systemic health.

Subgroups

- Subgroup A1 (n=14): Specimens prepared using Hand files (crown-down technique) were obturated with the cold lateral condensation technique.
- Subgroup A2 (n=14): Specimens prepared using Hand files (crown-down technique) were obturated with the thermoplasticized technique.
- Subgroup B1 (n=14): Specimens prepared using the Hyflex EDM rotary file system (crown-down technique) were obturated with the single cone technique.
- Subgroup B2 (n=14): Specimens prepared using the Hyflex EDM rotary file system (crown-down technique) were obturated with the thermoplasticized technique.
- Subgroup C1 (n=14): Specimens prepared by using a Neohybrid rotary file system (crown-down technique) were obturated with the single cone technique.

- Subgroup C2 (n=14): Specimens prepared by using Neohybrid rotary file system (crown-down technique) were obturated with the thermoplasticized technique.

Obturation:

In all the groups, AH PLUS sealer (Dentsply/Maillefer) was used.

Cone Beam Computed Tomography Post-Obturation Imaging:

To determine the POV of gutta-percha, a second scan of CBCT was done. POV was calculated individually in the coronal third, middle third, and apical third. The inner area of the void space was measured and multiplied by the thickness of the slice to obtain the volume of the void. The percentage volume (POV) was calculated with the formula: $(a-b \times 100/a)$, where a is the root canal space volume and b is the void space volume. Precise obturation techniques are essential to ensure the complete sealing of the root canal, preventing potential infections that could have systemic implications, including auditory conditions such as tinnitus. CBCT serves as a vital diagnostic tool to verify the integrity of the obturation process and identify voids that may contribute to such complications.

RESULTS

Using the linear measurements obtained from the CBCT analysis, the void volume, obturated material volume, and the volume percentage of the coronal, middle, and apical segments were determined.

Intergroup and intragroup comparison of the coronal third total volume percentage of all subgroups after obturation. In which the highest mean value was of the subgroup B2 (Hyflex EDM file + Thermoplasticized technique) (99.9960%) and the lowest was of Subgroup C1 (Neoendo neohybrid + Single cone technique) (93.4755%). The results were not statistically significant as P-value was 0.187. Improved obturation techniques, such as those in subgroup B2, may reduce the risk of coronal voids, thereby lowering the likelihood of microbial infiltration and systemic inflammation, which could indirectly influence conditions such as tinnitus.

Intergroup and intragroup comparison of the middle third total volume percentage of all subgroups after obturation in which the mean value was highest in the subgroup B2 (Hyflex EDM file + Thermoplasticized technique) (99.9279%). The results showed that the mean value was lowest in the C1 (Neoendo neohybrid Single cone technique) (94.0653%). The P-value of the middle total volume percentage was 0.187, which was considered to be statistically insignificant. Voids in the middle third, as observed in subgroup C1, could contribute to persistent low-grade infections. These infections may exacerbate systemic conditions, including auditory symptoms such as tinnitus, through inflammatory or neural pathways.

The intergroup and intragroup comparison of the apical third total volume percentage of all subgroups after obturation, in which the mean value was highest

in subgroup B2 (Hyflex EDM file + Thermoplasticized technique) (99.9977%) and was least in Subgroup A2 (Hand file + Thermoplasticized technique) (98.1929%). The P-value for the apical total volume percentage was 0.187. The P-value was considered to be statistically insignificant. Minimizing voids in the apical third, as seen in subgroup B2, may help prevent apical leakage and its associated risks of inflammation or infection, which could have systemic effects, including those influencing tinnitus.

The intergroup and intragroup comparison of the overall total volume percentage of all subgroups after obturation. For Subgroup B2 (Hyflex EDM file + Thermoplasticized technique), the value was highest - 99.9738%. The mean overall total volume percentage of the Subgroup C1 (Neoendo neohybrid Single cone technique) was the lowest - 95.7605%. The P-value was 0.000, which was statistically significant. The multiple intergroup comparisons of the overall volume percentage of the obturated material in the six subgroups after obturation using Turkey's Post Hoc test. When the Thermoplasticized technique (B2) was compared with the single cone technique (C1), the values were statistically significant ($P < 0.01$). When the lateral condensation technique was compared with other subgroups, the values were statistically insignificant. When the single cone technique was compared with other subgroups, the values were statistically insignificant. There was no difference in the results when the Thermoplasticized technique was compared with the other Subgroups.

DISCUSSION

All the portals of microbial entry in the root canal space can be sealed by 3D obturation of the canal system helps to seal, preventing secondary infection. Endodontic treatment failures mainly occur due to inadequate obturation into the root canal space. When there is an inadequate coronal seal, seepage of saliva and the penetration of the microorganisms from the oral cavity may result in apical periodontal inflammation. It is for these reasons that endodontically treated teeth should be restored by a direct filling or by a prosthetic crown within thirty days after the completion of root canal obturation⁸.

Traditionally, root canals were filled with a variety of materials. With time many of these materials were discouraged from use due non adherence to the ideal requirement as well as poor handling characteristics. Today, Gutta-percha has gained popularity and wide acceptance as an ideal root canal obturating material⁹.

The connection between dental health and systemic conditions, including auditory issues such as tinnitus, has been increasingly recognized. Studies have shown that dental infections or unresolved inflammatory processes originating from inadequate root canal treatment can contribute to systemic inflammation and potentially influence auditory pathways, exacerbating tinnitus symptoms¹⁰. This highlights the critical importance of ensuring optimal obturation to minimize voids that may lead to persistent low-grade infections¹¹.

The coronal and middle third of subgroup B2 (Hyflex EDM file + Thermoplasticized technique) showed the highest percentage obturation volume and minimum voids which can be attributed to the better homogenous mass of heated gutta percha which resulted in fewer voids, which also resulted in proper adaption of gutta percha to the root canal walls which might have increased the obturating material volume inside the canal which enhanced the percentage obturation volume.

The decreased number of voids present in the middle segments subgroup B2 can be attributed to the supreme inert core material, greater flow properties, transformation of phase, and less quantity of sealer in between the obturating material and the canal wall. Heated gutta percha changes to alpha-phase that is pliable. Hence, more flowable in consistency. The result can also be attributed to the design of the file and its cross section which is trapezoidal at the middle third of the file which might have resulted in increased obturating volume of the material into the canal which enhances the percentage obturation volume¹².

Voids observed in obturation, particularly in subgroup C1 (Neoendo neo hybrid + Single cone obturation technique), may contribute to the persistence of low-grade infections. Such infections can trigger inflammatory pathways or neural mechanisms that are associated with systemic conditions, including tinnitus¹³. Addressing these voids through advanced techniques is critical to reducing the risks of systemic effects.

An increased number of voids present in the coronal segments of subgroup C1 (Neoendo neo hybrid + Single cone obturation technique) can be attributed to the anatomy of root canal space of premolars in the coronal third where the canal space was not filled by the obturating material in single cone obturation technique. As a result, the space between the obturating material and the canal wall was filled by the sealer. As the sealer shows contraction during setting, it results in porosities in large volumes of sealer. The innovative off-centered rectangular cross-section of the file with 2-point contact with the canal wall also provided the asymmetric or swaggering movement of the file. The result of this study mentioned that the simple single-point obturation technique must be limited to the canals which are round and which have presumed the shape of the instrumentation¹⁴. In round and narrow, a matched taper single-cone obturation technique might be more effective. Crasta et al. performed a volumetric analysis of the root canals using SCT which were obturated using various techniques and stated that the single-cone obturation showed the least percentage obturation volume in the coronal third¹⁵. Due to a large amount of sealer, porosities in a large volume of sealer, setting contraction of the sealer, design, and cross-section of the file might have decreased the volume of obturating material inside the canal. In subgroup C1 (Neoendo neo hybrid + Single cone obturation technique), voids were observed at the middle third of root canals. It can be

attributed to the anatomy of the root canal of premolars and the innovative off-centered rectangular cross-section of the file with 2-point contact with the canal wall which provided asymmetric or swaggering movement.

The highest percentage obturation volume and minimum voids were seen in apical third subgroup B2, which could be the use of heated gutta percha which would have created less number of voids with better homogenous mass, which resulted in better adaption of gutta percha to the root canal walls¹⁶. In the apical part of the root canal, the taper is greater which increases the efficiency of the flow of irrigants. Therefore results in better debridement and subsequently better obturation. Hence this could be the advantage of the Hyflex EDM file system.

Thermoplasticized obturation techniques, as demonstrated by subgroup B2, provide significant benefits in reducing voids and improving sealing efficiency¹⁷. This may indirectly mitigate risks of systemic conditions, including auditory disorders such as tinnitus, by preventing microbial leakage and subsequent inflammation. Positioning these techniques as a preferred method in clinical practice can improve outcomes for both dental and systemic health.

This can also be attributed to the file design, cross section (triangular in the coronal third, trapezoidal in the middle one-third, and quadratic at the apical one-third). Significantly better obturation volume of material is seen in variable tapered canals, which might have increased the obturating volume of the material, Hence, enhancing the overall percentage of obturated volume. An earlier study by Allison et al. showed a strong correlation between canal taper and the quality of obturation and concluded that a flared (tapered) preparation had better obturation than the standardized technique. In the present study, results are by the Bhatt A et al. study in which volumetric analysis was compared between lateral condensation obturation technique, guttaFlow obturation technique, and thermoplasticized obturation technique (System B and Thermafil) using SCT and concluded that maximum volume of obturation was seen in the thermoplasticized technique¹⁸.

Subgroup A2 (Hand files + Thermoplasticized technique) showed the lowest percentage of obturation volume. The maximum voids present in the apical region may be due to the failure of the tip to reach the apical third as the canal was prepared with 2% Hand files, poor compaction, and entrapment of air.

CBCT evaluation in this study showed intermediate results with the lateral condensation technique. This technique showed lesser voids as compared to the single cone technique, as the accessory cones were interpressed with each other and also to the master cone with the help of sealer producing a dense obturation. In cold lateral condensation technique, showed more voids as compared to the Thermoplasticized obturation technique which could be because of the use of a spreader while

compaction of gutta-percha. Therefore, this results in the formation of spreader tracts between the filled gutta-percha and dentinal walls which produces comparatively less homogenous mass.

In light of these findings, interdisciplinary research exploring the implications of dental obturation techniques for systemic conditions, including auditory health, is essential. Advanced imaging tools like CBCT can play a pivotal role in identifying voids and improving treatment outcomes. Further studies should evaluate long-term impacts on conditions such as tinnitus to enhance our understanding of these connections^{19,20}.

In the multiple intergroup and intragroup comparison of overall total volume percentage of six subgroups after obturation was done using turkey post hoc. Statistical difference was seen in subgroups (C1- B2). The Statistical difference shows minimum voids in subgroup B2 (Hyflex EDM file + Thermoplasticized technique). This can be attributed to the file design, cross section (triangular at coronal one-third, trapezoidal in middle one-third, and quadratic at apical one-third), and its variable taper. The space between the obturating material and the canal wall was filled with a minimum quantity of sealer, which could have resulted in a minimum volume of porosities in the canal space. This might have increased the obturating volume of the material in the root canal which enhanced the overall percentage of obturation volume. It can also be due to the martensite and R phase of the Hyflex EDM file which revealed the most atypical structural properties like increased temperatures of phase transformation and greater hardness. Enhanced mechanical conduct of electrical discharged machined instruments would be due to the phase, composition, and enhanced hardness. Therefore, these qualities have an important influence on the clinical presentation of these instruments.

The obturation done using the traditional hand files has shown intermediate results. This could be attributed to the cross-sectional areas of K-files made up of twisted squares of the stainless steel alloy. During cleaning and shaping of the root canal system, it delivers tactile sensation and aids in determining the curvature, calcification, or any changes in the anatomy, which 2-D radiographs might not always detect²¹.

Maximum voids were seen in subgroup C1 (Neoendo neo hybrid + Single cone obturation technique) which can be attributed to the anatomy of the root canal of premolars where the canal space was not filled by the obturating material. As a result, the space between the obturating material and the canal wall was filled by the sealer. The lowest percentage of the obturated volume of the canal could also be due to the innovative off-centered rectangular cross-section of the file with 2-point contact with the canal walls which provided asymmetric or swagging movement. Our study demonstrated that the type and taper of the instrument had an outcome on the overall percentage volume of obturating material

where subgroup B2 exhibited better outcomes than other subgroups. This was by Caper et al. who stated that a greater percentage volume of gutta-percha was seen in canals prepared by the Hyflex EDM file system as compared to canals prepared by the Wave One file system. This would have contributed to the cross-section, design, and variable taper of the file which could have enhanced the volume of the obturating material. Therefore enhancing the quality of obturation material. On the contrary, using variable and constant taper finishing files determined that the type and taper of the instrument had no impact on the quality of obturation, as he could find no substantial difference in the percentage volume of gutta-percha²².

Therefore, based on the outcomes, we can suggest that the most universally used Single-cone technique has not been well regarded because of the anatomy of root canals of premolars, use of large amounts of sealer, porosities within the sealer, and setting contraction of the sealer are the main disadvantages of this technique. Single cone technique may not be ideal as it has shown maximum voids and minimum percentage obturation volume compared to thermoplasticized obturation techniques which have shown better outcomes. By familiarizing the thermoplasticized obturation technique as part of a prospectus, dental professionals can be made more pliable at expanding the material better which could lead to successful rates and more homogenous obturation.

The limitations of this study, are that it is not conclusive, and more research is needed to reveal the finest details of in-vivo to get dense three-dimensional obturation free of voids. Furthermore, clinical studies which would evaluate the long-term presentation in this regard would be helpful for further understanding the success of endodontic treatment.

CONCLUSION

In the current study, within the confines and constraints that are considered, it can be concluded that none of the used techniques in the study showed void-free obturation. The utmost percentage of obturation volume was attained with the thermoplasticized technique. Intermediate results were shown by the lateral condensation technique and the least percentage of obturation volume was obtained with the single-cone technique.

These findings highlight the need for further interdisciplinary research to explore the impact of dental obturation techniques on systemic conditions, including auditory disorders such as tinnitus. Understanding the role of void-free obturation in preventing infections or inflammation could offer valuable insights into managing systemic risks.

Moreover, improved obturation methods could play a critical role in reducing the risks of microbial leakage and persistent inflammation, which might influence tinnitus symptoms. Such advancements could benefit both dental and systemic health outcomes.

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