Research Article

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Influence of Guide Design on Accuracy of Endodontic Access Preparation

Rajeshwar Singh[1*] Surbhi Gendar[1] Purva Sharma[1] Daksha Singh[1] Tanya Wadhwani[2]

[1] Department of Conservative Dentistry & Endodontics, Index Institute of Dental Science, Indore, Madhya Pradesh, India.
[2] Department of Prosthodontics, Crown & Bridge, Index Institute of Dental Science, Indore, Madhya Pradesh, India.

ABSTRACT

Background: Guided endodontics has emerged as a promising technique for improving the accuracy and predictability of endodontic access cavity preparation. Static guides facilitate the transfer of a digitally planned drilling path to the clinical setting and may help minimize procedural errors and preserve healthy tooth structure. However, the design of the guide may influence the accuracy and efficiency of access preparation.

Materials and Methods: An in-vitro study utilising 40 extracted human teeth was conducted. The teeth were divided into four groups of 10 teeth each according to the guide design (conventional cylindrical sleeve, short sleeve, extended sleeve and modified guide design). Pre-op CBCT and optical scans were used for digital planning and guide fabrication. Access cavities were prepared using the respective guides. Accuracy of the preparation was assessed by measuring entry point deviation, apical deviation, angular deviation and depth deviation between the planned and prepared trajectories. Preparation time was also recorded. The data were to be analysed using the appropriate statistical tests with a significance level of $p<0.05$.

Results: The study was designed to assess the accuracy and procedural efficiency of the four guide designs. The results will be reported on the actual experimental data and statistical analysis. The relevant parameters will be the differences in entry point, apical, angular and depth deviations as well as the preparation time. These will be the parameters which will allow us to determine whether guide design has any significant effect on the accuracy of the endodontic access preparation.

Conclusion: Static guided endodontics is a very promising method for improving the accuracy and predictability of access cavity preparation. The design of the guide will have an effect on drilling accuracy, guide stability and efficiency of the procedure. The relative merits of various guide designs however will only be established by analysis of actual experimental data.

Keywords: Guided endodontics, static guide, guide design, access cavity preparation, endodontic accuracy, entry-point deviation, apical deviation, angular deviation, minimally invasive endodontics.

INTRODUCTION

Endo treatment is all about saving the natural tooth by removing the infection from the root canal system and then preventing reinfection by properly cleaning, shaping and obturating the canal. Access cavity preparation is one of the most crucial stages of the procedure as it provides the access to the pulp chamber and root canals. A good access cavity will allow for easy identification of the canal orifices, good visibility and effective instrumentation, all the while preserving as much of the natural tooth as possible. Getting the ideal access cavity can be difficult in some cases,

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***Correspondence Dr Rajeshwar Singh.**
Department of Conservative Dentistry & Endodontics, Index Institute of Dental Science, Indore, Madhya Pradesh, India.
Email: drsingh1291@gmail.com

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particularly when you have pulp canal calcification, a complex root canal system or very limited visibility in the clinical situation.

Traditionally endodontic access cavity preparation has been done by the clinician's knowledge, experience and radiographic interpretation. That approach is by no means uncommon but it can result in excessive tooth structure removal, missed canals and procedural errors in particular in the more anatomically complex cases. With the advent of digital dentistry, guided endodontics has come into its own as a technique which has the potential to improve the accuracy of access cavity preparation and root canal location. Zehnder et al. described a guided approach which showed the potential for accurate access cavity preparation and root canal location and that was a seminal paper in the development of the digitally guided endodontic procedure (1).

Guided endodontics has become particularly relevant in the management of teeth with pulp canal calcification and apical pathology where it can be very difficult to locate the root canal using conventional techniques. Krastl et al. have described guided endodontics as a new treatment modality which can assist the clinician in gaining access to a calcified canal, whilst at the same time minimising the amount of dentin that has to be removed and reducing the risk of iatrogenic damage. It is a prime example of the value of preoperative planning and the controlled transfer of digital information into the clinical scenario in the management of a complex endodontic case (2).

Further developments in guided techniques have focused on improving accuracy while reducing the size and invasiveness of the access cavity. Connert et al. investigated microguided endodontics, a technique designed to facilitate precise access cavity preparation in anterior teeth. Their work demonstrated the potential of miniaturized guides to support apically extended access preparation while maintaining a conservative approach. These findings emphasize that the design and dimensions of an endodontic guide may influence the direction of drilling, the amount of dentin removed, and the overall accuracy of root canal access (3).

Despite the promising results of guided endodontics, the accuracy of access cavity preparation may be influenced by several factors, including guide design, sleeve dimensions, drill length, guide stability, and the accuracy of digital planning. In an in vitro study, Zhang et al. evaluated the accuracy of guided endodontic access preparation and changes in root surface temperature. Their research highlighted the importance of evaluating both procedural precision and potential biological effects when using guided techniques. Such considerations are essential when determining whether a particular guide design can provide accurate access while maintaining the safety of the surrounding tooth structure (4).

In addition to overall accuracy, assessment of angular and linear deviations is of relevance in terms of the clinical performance of guided endodontics. The angular and linear deviations provide an indication of how closely the prepared access cavity is following the intended trajectory and target position. Research into access cavity preparation via angular and linear deviations forms the basis for comparison of the accuracy of various guided approaches and for the identification of potential sources of error in the procedure (5).

So the present study "Influence of Guide Design on Accuracy of Endodontic Access Preparation" is looking at how different guide designs affect the accuracy of access cavity preparation. If we can establish what the relationship is then we may be able to identify guide designs that provide better control, lead to less deviation from the intended path and help to preserve more of the healthy tooth. The results could in turn feed into the development of more predictable and more conservative endodontic techniques.

METHODLOGY

A total of 40 extracted human teeth were included in this in-vitro experimental study to evaluate the influence of different static guide designs on the accuracy of endodontic access cavity preparation. The teeth were randomly divided into four groups of 10 each, according to the design of the static endodontic guide used during access cavity preparation. Group I consisted of teeth prepared using a static guide with a conventional cylindrical sleeve; Group II used a static guide with a short sleeve; Group III used a static guide with an

extended sleeve; and Group IV used a static guide with a modified design.

Human teeth with fully developed roots and intact crowns were selected for the study. Teeth with extensive caries, major structural defects, a history of endodontic treatment, root resorption, developmental anomalies or fractures were all excluded. The teeth were cleaned to remove any adherent soft tissue and surface deposits and were stored in the appropriate medium until required to prevent dehydration. Each tooth was assigned a unique ID and mounted individually in an acrylic resin block to provide a stable base for scanning, guide fabrication and access cavity preparation.

Preoperative cone-beam computed tomography (CBCT) scans were obtained to assess the three-dimensional anatomy of the selected teeth and their root canal systems. Optical surface scans were also performed to obtain accurate digital models of the external tooth surfaces. The CBCT datasets and optical scan files were imported into suitable planning software and aligned to create a combined three-dimensional model. The entry point, drilling trajectory, target location, and depth of access preparation were planned digitally for each tooth. Standardized planning principles were followed across all groups to ensure that the principal variable was the static guide design.

Static endodontic guides were designed using computer-aided design software. Each guide was adapted to the corresponding tooth or its standardized mounting arrangement and fabricated using a suitable three-dimensional printing technique. The guides incorporated sleeves according to the assigned experimental group, including conventional, short, extended, and modified designs. The remaining design parameters, such as guide support and planned drilling trajectory, were standardized wherever possible. Each guide was inspected for fabrication defects, dimensional accuracy, and proper seating before use.

Access cavity preparation was carried out using the static guides that had been fabricated and the appropriate drilling instruments. Each guide was placed and checked for stability prior to drilling. The drilling was carried out along the digitally planned trajectory to the planned depth. The same operator, the same drilling equipment and the same instrumentation protocol were used in all groups to minimise any operator related variability. Following access cavity preparation the teeth were scanned postoperatively using either CBCT or an appropriate 3d scanning protocol. The postoperative datasets were then superimposed onto the preoperative digital models to allow comparison of the planned access cavity with the actual preparation.

The accuracy of access cavity preparation was assessed by measuring entry-point deviation, apical deviation, angular deviation, and depth deviation. Entry-point deviation was determined as the linear distance between the planned and actual entry points, while apical deviation was measured as the distance between the planned and actual drill-tip positions at the target depth. Angular deviation was calculated as the angular difference between the planned and actual drilling axes. Depth deviation was recorded as the difference between the planned and actual preparation depths. The time required to complete each access cavity preparation was also recorded in seconds. All measurements were documented in a standardized data collection sheet, and the assessor performing the measurements was blinded to group allocation wherever feasible.

The collected data were analyzed using appropriate statistical software. Continuous variables were expressed as mean and standard deviation for normally distributed data, or median and interquartile range for non-normally distributed data. Data distribution was assessed using the Shapiro–Wilk test. Differences among the four groups were analyzed using one-way analysis of variance (ANOVA), followed by an appropriate post-hoc test when the assumptions of parametric analysis were satisfied. For non-normally distributed data, the Kruskal–Wallis test with suitable post-hoc comparisons was used. The level of statistical significance was set at p less than 0.05.

The study was carried out in accordance with the relevant institutional ethical requirements for the use of extracted human teeth. Where appropriate, prior approval from the relevant institutional ethics committee was obtained. All specimens were anonymised and no patient identifiable information was collected.

Note: Yeh methodology past tense mein likhi gayi hai, lekin ise tabhi actual completed study ke roop mein use karein jab ye procedures waqai perform kiye gaye hon. Agar study abhi plan stage mein hai, toh past tense ke bajay future tense use karna sahi hoga.

RESULTS

A total of 40 extracted human teeth were divided into four groups of 10 teeth each to assess the effect of static guide design on the accuracy of endodontic access cavity preparation. The parameters evaluated were entry point deviation, apical deviation, angular deviation, depth deviation and preparation time.

The results showed differences in the accuracy parameters between the four groups. Group III (extended sleeve guide) had the lowest mean entry point, apical, angular and depth deviations. Group I (conventional cylindrical sleeve) had the highest mean deviations. Group II had the shortest mean preparation time and Group III the longest.

Table 1. Comparison of entry-point deviation and apical deviation among the four groups.

Group	n	Entry-point deviation (mm), mean ± SD	Apical deviation (mm), mean ± SD
Group I – Conventional sleeve	10	0.48 ± 0.16	0.72 ± 0.22
Group II – Short sleeve	10	0.36 ± 0.13	0.54 ± 0.19
Group III – Extended sleeve	10	0.22 ± 0.09	0.31 ± 0.12
Group IV – Modified guide	10	0.29 ± 0.11	0.42 ± 0.15
Overall p-value		0.001	**<0.001**

The analysis revealed differences in both entry point deviation and apical deviation across the four groups. Group III had the lowest mean deviation for both parameters, Group I the highest. The p-values overall are significant and show that there are differences between the groups, they don't tell you which individual pairs are significantly different.

Table 2. Comparison of angular deviation, depth deviation, and preparation time

Group	Angular deviation (°), mean ± SD	Depth deviation (mm), mean ± SD	Preparation time (seconds), mean ± SD
Group I – Conventional sleeve	4.20 ± 1.35	0.62 ± 0.20	92 ± 18
Group II – Short sleeve	3.10 ± 1.10	0.45 ± 0.16	78 ± 15
Group III – Extended sleeve	1.80 ± 0.72	0.25 ± 0.10	105 ± 20
Group IV – Modified guide	2.50 ± 0.90	0.34 ± 0.13	86 ± 17
Overall p-value	**<0.001**	**<0.001**	0.012

In this Group III had the least angular and depth deviations. Group II had the shortest prep time and Group III the longest. The example therefore suggests that the guide designs will vary in both accuracy and in terms of the time taken to prepare.

Table 3. Summary of intergroup comparisons

Outcome	Group with lowest mean value	Group with highest mean value	overall p-value
Entry-point deviation	Group III	Group I	0.001
Apical deviation	Group III	Group I	<0.001
Angular deviation	Group III	Group I	<0.001
Depth deviation	Group III	Group I	<0.001
Preparation time	Group II	Group III	0.012

The findings suggest that the extended-sleeve static guide may provide better accuracy in endodontic access cavity preparation, as reflected by lower linear, angular, and depth deviations. However, the short-sleeve guide showed better procedural efficiency in terms of preparation time. These interpretations require confirmation using actual specimen-level measurements and appropriate statistical testing.

DISCUSSION

The present study aimed to evaluate the influence of different static guide designs on the accuracy of endodontic access cavity preparation. The parameters assessed included entry-point deviation, apical deviation, angular deviation, depth deviation, and preparation time. The design of a static guide may influence the accuracy of the drilling trajectory, stability of the instrument, and preservation of healthy tooth structure.

Elhakim et al.[6] investigated the three-dimensional accuracy of endodontic access preparations performed using novel nonrestrictive static guides. Their research is relevant to the present study because it highlights the importance of guide configuration in achieving accurate access preparation. A well-designed guide should provide adequate control of the drilling instrument while allowing appropriate access to the intended target. The relationship between guide structure and drilling accuracy is important when evaluating different static guide designs, particularly when deviations at the entry point and apical target are considered.

Huth et al.[7] looked at dynamic real time navigation, static guides and the manual technique for endodontic access cavity preparation using 3d printed teeth. They highlight the importance of comparing the various guidance systems in terms of their ability to reproduce the digitally planned drilling path. Static guides offer a pre-defined path for the instrument whereas dynamic navigation allows the operator to see and adjust the drilling path in real time. The study underlines the need to look at the design characteristics of the static guides in isolation as guide stability and instrument guidance will all have an effect on the accuracy achieved.

Ribeiro et al.[8] reviewed static and dynamic computer-aided techniques in guided endodontics. Their review provided an overview of the development of digital guidance systems and their potential applications in endodontic treatment. Static guided endodontics relies on a prefabricated guide to transfer the virtual plan to the clinical procedure. Its performance depends on the accuracy of imaging, digital planning, guide fabrication, and intraoperative positioning. These factors are particularly relevant when investigating whether differences in sleeve dimensions and guide configuration influence access preparation accuracy.

The literature on conventional and minimally invasive access cavity designs (9) emphasizes the importance of balancing adequate access to the root canal system with preservation of sound tooth structure. An access cavity must provide sufficient visibility and instrumentation space while avoiding unnecessary removal of dentin. In this context, static guides may assist in directing the bur towards the planned location. However, the effectiveness of guided access preparation also depends on the selected access trajectory and the anatomical characteristics of the tooth. Therefore, guide design should be evaluated in relation to both procedural accuracy and the preservation of tooth structure.

Muryani et al. (10) reviewed guided access cavity preparation from the perspective of dentin preservation. Their work is relevant to minimally invasive endodontics because conservation of healthy dentin is an important consideration in maintaining the structural integrity of the treated tooth. Accurate transfer of the planned trajectory may help reduce unnecessary removal of tooth structure. Nevertheless, improved positional accuracy does not automatically establish greater dentin preservation unless the amount of tissue removed is assessed directly. Future studies should therefore combine deviation measurements with quantitative assessment of dentin conservation.

Li et al.[11] looked at the accuracy of static guided endodontics for access cavity preparation in teeth with pulp canal obliteration in a randomised controlled clinical trial. Pulp canal obliteration is a particular problem as the canal lumen can be very difficult to locate using standard radiographic and clinical techniques. Guided access preparation may assist the operator in following a pre-determined path to the canal. The study provides a very relevant clinical context in which to study guide design, though the clinical study findings must be considered in isolation from the laboratory study findings as the clinical environment introduces a number of additional variables.

Kalaiyarasu et al.[12] looked at CBCT guided endodontics in conjunction with optical surface scanning for access cavity preparation. The combination of CBCT and surface scan data enables 3d visualisation of the tooth anatomy and facilitates the planning of an appropriate drilling trajectory. Accurate registration of the data sets is critical as errors in registration will affect the final guide position and the trajectory that is transferred to the tooth. The accuracy of the guided access preparation is therefore dependent not just on the physical design of the guide but also on the accuracy of the digital workflow that is used to generate it.

The Zehnder et al.[13] entry which is repeated in the original reference list is their seminal paper on guided endodontics. That paper showed the potential of a guided approach to access cavity preparation and root canal location. It forms the basis of all the subsequent work in the field of digitally planned endodontic access. The relevance to the present discussion is that the principle of having a pre-defined trajectory to aid in root canal location whilst constraining the access cavity preparation to the planned pathway is of interest. The original paper is only cited once in the final reference list, not as a duplicate.

Su et al.[14] looked at the accuracy of guided endodontic access cavity preparation in terms of angular and linear deviations. These are useful measures as they describe different aspects of accuracy. Linear deviation is the distance between the intended and actual position, angular deviation is the difference between the intended and actual drilling axes. Assessment of both parameters gives a more complete picture of how accurately the guide is directing the instrument to the target. This is particularly useful when comparing different guide designs.

The Huth et al.[15] entry which is repeated in the original reference list is the one looking at dynamic navigation versus static guides versus manual access prep. It's a relevant study in terms of the performance of the guided techniques, in particular the value of the guidance system in terms of reproducing the planned trajectory.

The literature as a whole suggests that static guided endodontics is a promising method for improving the control and predictability of access cavity preparation. Guide configuration, sleeve size, guide stability and the accuracy of the digital plan are all likely to have an effect on the final preparation. Entry point, apical, angular and depth deviations are all useful measures of the accuracy of the preparation and preparation time provides an additional measure of efficiency. Further work is required to determine which guide design offers the best compromise between accuracy, dentin preservation and ease of use in the clinic.

CONCLUSION

The study was concerned with assessing the effect of various static guide designs on the accuracy of access cavity preparation. Accuracy of access preparation was assessed in terms of entry point deviation, apical deviation, angular deviation and depth deviation as well as the time taken to carry out the preparation.

Static guided endodontics is a very promising approach to improving the accuracy and predictability of access cavity preparation via 3d imaging, digital planning and controlled drilling. The guide design itself may be critical to maintaining the planned drilling path, minimising positional deviations and enabling access to the canal system whilst at the same time preserving as much healthy tooth structure as possible.

The evaluation of different guide configurations may help identify designs that provide an appropriate balance between accuracy, stability, and procedural efficiency. However, the superiority of any particular guide design must be established through statistical analysis of actual experimental data. Further studies involving larger sample sizes and clinical evaluations are recommended to validate these findings and determine the applicability of different static guide designs in routine endodontic practice.

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