The accuracy and temperature change on the root surface using guided endodontics in root canal preparation

Cuifeng Zhang
the Affiliated Stomatological Hospital of Nanjing Medical University

Xiao Zhao
the Affiliated Stomatological Hospital of Nanjing Medical University

Cheng Chen
the Affiliated Stomatological Hospital of Nanjing Medical University

Jingyan Wang
the Affiliated Stomatological Hospital of Nanjing Medical University

Peiyu Gu
the Affiliated Stomatological Hospital of Nanjing Medical University

Junchi Ma
the Affiliated Stomatological Hospital of Nanjing Medical University

Daming Wu (✉ wdmning@njmu.edu.cn)
the Affiliated Stomatological Hospital of Nanjing Medical University

Jin Li
the Affiliated Stomatological Hospital of Nanjing Medical University

Research Article

Keywords: Cone-beam computed tomography, Guided endodontics, Root canal preparation, Temperature

Posted Date: July 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1798578/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published at BMC Oral Health on November 16th, 2022. See the published version at https://doi.org/10.1186/s12903-022-02548-w.
Abstract

Background
Guided endodontics have high accuracy and are successful techniques that had been gradually used in endodontics in recent years. However, the guided bur produces excessive heat during continuous rotation and friction with root canal walls. It is not clear whether the degree of temperature increase may lead to periodontal ligament and alveolar bone damage.

Methods
Forty single-rooted premolars were scanned using CBCT and intra-oral scanner, and 3D-printed guided plates were made with the pre-designed access. A custom-made guided bur was used to prepare the access cavities. The postoperative CBCT data and pre-designed pathways were matched to evaluate the deviation between planned and virtual path. Another 18 single-rooted premolars were accessed with the guided plates and bur, ET20 and ProTaper F3, respectively. The temperature changes on the root surfaces were inspected with a thermocouple thermometer.

Results
The average deviation on the tip and the base of the bur were 0.30 mm and 0.28 mm (mesial/distal), and 0.28 mm and 0.25 mm (buccal/lingual). The average angle deviation was 3.62°. The mean root surface temperature rise of the guided endodontics group was 3.07°C, which was lower than that of the ProTaper F3 group (8.90°C) ($P < 0.05$) and was significantly lower than that of ET20 group (15.70°C) ($P < 0.01$).

Conclusions
The access cavity preparation performed with guided endodontics has feasible accuracy and low temperature rise on the root surfaces, indicating their high reliability and safety in clinical applications.

Introduction
Access to the pulp chamber and achieve unobstructed, direct access to the root canal system is the first but crucial step for nonsurgical root canal treatment (RCT) [1]. A properly access cavity preparation may achieve a smooth, straight-line path to the apical foramen without change in the original orientation of the root canal [2, 3]. Moreover, access cavity designs influence the ability of endodontic files to plane the walls of the root canals [3]. Therefore, the optimal result of adequate enlarging, shaping, cleaning, disinfection and obturation of all pulpal spaces is difficult to achieve if the access cavity is not prepared properly.
Traditionally access cavities have been prepared according to the occlusal anatomy. However, it is inaccurate to completely rely on the occlusal anatomy because the crown morphology can change by abrasion, caries or defective restorations, and the roots may not be perpendicular to the occlusal surface of the teeth, which will lead to the occurrence of some procedural errors [4]. In addition, orthodontic treatment, trauma, chronic inflammatory and age processes often cause pulpal degeneration and concomitant narrowing of the root canal systems [5, 6]. Pulpal spaces which demonstrate significant calcifications may present problems with locating, penetrating and negotiating the chambers and root canals [7]. The traditional access needs to remove sufficient tooth structure to allow instruments access to each canal orifice easily without interference from canal walls. But these operations are contrary to the concept of minimally invasive endodontic preparation, which advocate the preservation of immunological functions and retaining structural integrity of the tooth [8]. The clinical application of magnification, transillumination and ultrasonic tips are effective way to locate and negotiate of the canals [9]. However, the direction of the ultrasonic instruments should adjust timely to avoid perforations or fracture due to excessive loss of tooth structure with the help of radiographs taken at different angles. Most of these cases require a long time of operation [10], which bring challenges to both doctors and patients.

Recently, with the improvement of cone-beam computed tomography (CBCT) and three-dimensional (3D) rapid prototyping manufacturing technology, the technique of guided endodontics has been introduced to the field of endodontic therapy, including access cavity preparation and endodontic surgery [11, 12]. Guided endodontics have high accuracy and are successful techniques without being affected by the operator’s experience when comparing the drilled path to the planned treatment [13]. They help clinicians achieve predictable and safe results, avoid unnecessary removal of tooth tissue or complications, and improve the treatment prognosis [14, 15]. Although the average planning time takes long, the preparation of the access cavity using the endodontic guides require only tens of seconds on average [16–18], which provides a good medical experience for clinicians and patients. Guided endodontics may be a promising method for the endodontic or surgical treatment of complex cases.

However, previous studies used different software to design guided plates and measure deviation, and the diameters of the guided burs (0.85 ~ 1.3mm) were also different, which led to slightly changes in accuracy. It is possible that the guided burs with smaller diameter may have smaller deviation, avoiding cutting dentin tissue excessively. In addition, the guided bur produces excessive heat after continuous rotation and friction with root canal wall, it is not clear whether the degree of temperature increase may lead to periodontal ligament and alveolar bone damage. Therefore, the aims of this study were to evaluate the accuracy and temperature change on the root surface of guided access cavity preparation.

Materials And Methods

Stage 1: Accuracy measurement

Sample preparation
The approval for this study was obtained from the Ethical Committee Department of the Affiliated Stomatological Hospital of Nanjing Medical University (PJ2018-022-001). Written informed consents were acquired from all participants and/or their legal guardian for study participation. Mature human single-rooted premolars without endodontics treatment, crown restorations, caries, periapical lesion, root resorption and fractures were collected from Aug 2018 to Dec 2020. After removing the residual soft and hard tissues, they were randomly fixed in a curved epoxy model, and were scanned using a CBCT scanner (NewTom 5G, QR srl, Verona, Italy) at 110 kV, 3 ~ 9mA, a field of view of 8cm×12cm, a basic voxel size of 0.30 mm by an experienced radiologist based on the manufacturer's operation instructions. The CBCT data was stored, reconstructed and analyzed using NNT 10.0 software (QR srl, Verona, Italy). The teeth with similar root length and root canal diameter were selected.

**Manufacture guided plates**

Forty selected premolars were scanned with 3shape Trios intra-oral scanner (TRIOS 3, 3Shape, Denmark). The standard tessellation language (STL) files created by the intra-oral scanner were matched with the CBCT data in a dental implant design software (Dengital 3D Implant Sys software, Fox medical tech, China) to design the guided plates. A virtual bur with 0.8mm diameter and 18mm work length was designed for the access cavity preparation using the software, and was used to simulate the planned paths (Fig. 1A, C).

Then the matched data were imported into a 3D-printer (Projet 7000MP, 3D System Int, USA), and epoxy resin was used to make 3D-printed guided plates(Fig. 1D). The guided metal tubes embedded in the plates have a wide inner diameter (3.5mm) to be compatible with two different sizes of inner sleeves. The inner sleeves are cylindrical tubes with the same outer diameter to match the guided metal tubes. But they have different inner diameters (0.85mm and 1.4mm) to guided diamond bur (1.4mm diameter) and the custom guided bur (0.8mm diameter), respectively.

**Access cavity preparation**

The 3D-printed guided plates were position on the models and their correct and reproducible fitting were examined carefully(Fig. 1E). A high-speed diamond bur (Comet, Germany) with a maximum diameter of 1.4mm was used to remove the enamel of the access hole. The access cavity was prepared using a specially bur (0.8mm diameter and 18mm blade) (Fig. 1B) made of medical high hardness stainless steel material at 800 rpm (X-SmartTM, Dentsply Maillefer, Japan) to the apical third of the roots. The bur was cleaned regularly and the canals were irrigated using a 27-gauge needle and 2% sodium hypochlorite during preparation to completely remove dentinal debris. A 10-size K file (21mm, MANI, INC) was used to check the root canal and to establish the working length. Finally, the instrumented canals were irrigated using 17% EDTA and were dried using paper points and scanned again using the CBCT scanner as described above.

**Accuracy measurement**
The STL data of the guided rod and the guided plate in the design engineering file was exported, and was imported into Magics 23.0 software (Materialise NV, Leuven Belgium). A cylinder part with the same height and diameter as the guided bur was created, and was aligned to the STL data of the guided plate to represent the virtual paths. Then the STL files of the virtual paths and the data of the preoperative tooth surface were import into Mimics 21.0 software (Materialise NV, Leuven Belgium), and were aligned with the postoperative CBCT image by using a point registration tool (Fig. 2).

The preoperative images were measured in 2 base point, the top point (apical direction) of the bar as T-Point, and the base point (the entrance near the crown) of the bar as B-Point. The deviation between the actual T-point and the pre-designed T-point was measured from both buccolingual and mesiodistal directions. Deviation of angle was automatically calculated and output by the Mimics 21.0 software. The part of artificial identification point was operated by two experienced experimenters independently.

Stage 2: Temperature measurement

Specimen preparation

The access preparation was performed on 18 selected premolars using a high-speed diamond bur. A 10-size K file (21mm) was used to check the root canals. The canals were prepared with ProTaper nickel titanium (NiTi) rotary instruments (X-SmartTM, Dentsply Maillefer, Japan) to middle third of the root length. Then, the specimens were scanned using the CBCT scanner as described above. All CBCT scans were analyzed by NNT software 10.0 at axial planes. The root surface was marked at 1.2 mm thickness of root canal wall. Then the specimens were divided into 3 groups (n = 6): Ultrasonic tip (ET20, Satelec, Pierre Rolland, France), ProTaper F3 file (Dentsply, Ballaigues, Switzerland) and the guided endodontics. The 3D-printed guided plates for the guided endodontics group were made as described above. Standardized bisecting angle digital periapical radiographs were taken of all the teeth from the buccolingual direction using a CCD (Sidexis, Siemens, Germany) system to ensure that the test instruments can directly reach the marked points.

Study model

A 3mm thick epoxy resin plate was made to fix onto the cemento-enamel junction of the premolars (Fig. 3A). All roots were completely and clearly exposed. A K-type thermometer (Center 301, type-K, tenmars, Taiwan, 0.1 °C) was fixed onto the marked point of the root surface with the PTFE seal tape to monitor the temperature change according to the manufacturer’s instructions at room temperature (25 °C) (Fig. 3B-D). Temperature changes were recorded continuously every second but were inspected at 20-second intervals up to 120 seconds.

Experimental processes

ET20 group: a ET20 ultrasonic tip was inserted into the canal and reached the marked point of the root. The power level of the ultrasonic device (P5XS, Satelec, Cedex, France) was set at scale 8. The ET20 ultrasonic tip continuously worked for 60 seconds without coolant.
ProTaper F3 group: a F3 file was inserted into the canal and reached the marked point of the root, and continuous working for 60 seconds without coolant. A motor and handpiece (X-Smart TM, Dentsply Maillefer, Tochigi, Japan) were used, the speed was set at 800 rpm, and the torque was set at 1.0 N·cm.

Guided endodontics group: guided plate was placed on the models, and the correct and reproducible fitting was examined. The special design bur was inserted into the canal and reached the marked point of the root, and continuous working for 60 seconds as ProTaper F3 group.

The temperature on the root surfaces of all the teeth was recorded automatically using the thermometer.

**Statistical analysis**

All data were showed as means ± standard deviation (SD) and analyzed using SPSS 26.0 software (SPSS Inc., Chicago, IL). The 95% confidence interval (CI) of the deviation of the planned and prepared root canal preparation were calculated. The mean temperature rise at the same time between the experimental groups was compared with Kruskal-Wallis test. The level of significance was set at $P < 0.05$.

**Results**

**Stage 1: Accuracy measurement**

Thirty-six teeth were successfully reach the working length. Two teeth were excluded due to model dislocation, the other 2 teeth were excluded due to the broken bur. The mean of absolute difference, minimum and maximum of deviation at bur’s tip and base of the planned and prepared canals in mesial/distal, buccal/lingual (mm) directions and angle (°) were showed in Table 1.

<table>
<thead>
<tr>
<th>Tip of the bar</th>
<th>Base of the bar</th>
<th>Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-D(mm)</td>
<td>B-L(mm)</td>
<td>M-D(mm)</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>0.30 ± 0.20</td>
<td>0.28 ± 0.23</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.75</td>
<td>0.98</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.23 ~ 0.36</td>
<td>0.20 ~ 0.36</td>
</tr>
</tbody>
</table>

**Stage 2: Temperature measurement**

The temperature on the root surface during the 60 seconds of operation were showed in Table 2 (every 10 seconds). The root surface temperature rose gradually and peaked at 60 seconds in all groups. The root surface temperature of the guided endodontics group raised 3.07°C, which was lower than that of the F3 group (8.90°C) ($P < 0.05$) and was significantly lower than that of ET20 group (15.70°C) ($P < 0.01$). There
were significant temperature changes between guided endodontics and ET20, guided endodontics and F3 after 10 seconds ($P<0.05$).

<table>
<thead>
<tr>
<th>Time (second)</th>
<th>ET20</th>
<th>F3</th>
<th>Guided endodontics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25.63 ± 0.06</td>
<td>25.60 ± 0.00</td>
<td>25.63 ± 0.06</td>
</tr>
<tr>
<td>10</td>
<td>28.60 ± 2.33</td>
<td>27.73 ± 0.40</td>
<td>26.27 ± 0.45</td>
</tr>
<tr>
<td>20</td>
<td>31.03 ± 2.76</td>
<td>30.20 ± 1.22</td>
<td>26.90 ± 0.82</td>
</tr>
<tr>
<td>30</td>
<td>34.87 ± 0.72</td>
<td>31.80 ± 0.96</td>
<td>27.43 ± 1.04</td>
</tr>
<tr>
<td>40</td>
<td>37.70 ± 1.05</td>
<td>32.97 ± 0.80</td>
<td>27.90 ± 1.15</td>
</tr>
<tr>
<td>50</td>
<td>39.53 ± 0.96</td>
<td>33.83 ± 0.85</td>
<td>28.23 ± 1.38</td>
</tr>
<tr>
<td>60</td>
<td>41.33 ± 0.59</td>
<td>34.50 ± 0.76</td>
<td>28.70 ± 1.49</td>
</tr>
</tbody>
</table>

**Discussion**

In recent years, there have been some pre-clinical studies evaluated the accuracy of guided endodontics and found that the accuracy of them was reliable [19–21]. For example, Buchgreitz et al [19] reported that the mean distance between the drill path and the target was significantly lower than 0.7 mm. Zehnder et al [20] reported a mean angle deviation of 1.81°, a mean mesial/distal deviation at the base of the bur of 0.21 mm, buccal/oral of 0.2 mm and apical/coronal of 0.16 mm; a mean mesial/distal deviation at the tip of the bur of 0.29 mm, buccal/oral of 0.47 mm and apical/coronal of 0.17 mm. Connert et al [21] reported a mean angle deviation of 1.59°, a mean mesial/distal deviation at the base of the bur of 0.12 mm, buccal/oral of 0.13 mm and apical/coronal of 0.12 mm; a mean mesial/distal deviation at the tip of the bur of 0.14 mm, buccal/oral of 0.34 mm) and apical/coronal of 0.12 mm.

In this study, the mean of absolute difference at the tip of the bur in mesial/distal direction was 0.30 mm and in buccal/lingual direction was 0.28 mm, and at the base of the bur was 0.28 mm 0.25 mm, respectively. The results were consistent with previous studies [19–22], indicating that the high precision of the guided endodontics with a negligible effect of the operators and the software for design and measurement. The mean deviation of angle was 3.62°, which were slightly higher than these of previous studies [20, 21]. Possible explanation is that the diameter difference between the metal sleeve inner and the special design bur were small (0.85mm vs. 0.8mm), the bur rubbed the metal sleeve inner at high speed, resulting in the slight vibration of the guided plates and thermal deformation of the inner wall of the sleeve, which then led to the deviation of the path. Reduce tolerance between bur and the slightly oversized sleeve may improve the precision of cavity preparation [19]. In addition, a novel sleeveless 3D-printed guide maybe an alternative to the conventional guide design to gain access to obliterated root canals [23].
It is indicated that periodontium would be injured when the temperature raised more than 7°C and the bone tissue would undergo reversible histologic changes when temperature raised more than 10°C for 1 minute [24]. Although dentin is a relatively good insulator, a temperature rise on the external root surfaces with a consequential alveolar bone reaction has been reported after long-term use of warm gutta-percha obturation techniques, NiTi files, retreatment or disinfection with laser and the operation of ultrasonic instruments [25–28]. For example, Madarati et al [26] measured the temperature rise on the external root surface during the removal of separated NiTi files according to the type of ultrasonic tips, power setting and contact time, and found that the smaller the tip, the higher the power and the longer the contact time, the higher the temperature rise. The average temperature can rise to 17.5°C without coolant. Budd et al [28] measured the temperature rise on the root surface cause by ultrasonic post removal using different devices and techniques, and found that the temperature of root surface raised 12 °C at 60s and 15.6°C at 120s. There were significant differences in temperature rise as a function of ultrasonic device, location on the tooth and cooling method utilized for post removal.

In this study, the temperature measurement points were set on the external surface of the middle third of the roots with the same dentin thickness confirmed using pre-operation CBCT images. The root surface temperature increased gradually and peaked at 60 seconds in all groups, while the average temperature rise of the guided endodontics was lower than that of F3 and was significantly lower than that of ET20. In addition, the root surface temperature of the guided endodontics raised 3.07°C, which was lower than the safe temperature rise reported in the literatures, indicating the safety of the guided endodontics. The ET20 group showed the highest temperature rise and was higher than these of previous studies, which may be related to no coolant during operation, the higher power of ultrasonic device and the different thickness of root canal wall compared with other studies.

It was important to point out that all experimental instruments continuously worked in air without simulating any heat dissipation in this study. This kind of continuous work without coolant can be applied to a few clinical practice, such as removing dentin around separated instruments using ultrasonic tip in order to keep vision clear. Periodontal blood flow protects the alveolar bone from thermal injury during thermoplasticized root canal obturation [29]. Therefore, it's reasonable to speculate that the heat generated by access cavity preparation under the guided endodontics can be better dissipated by intermittent cutting, cooling with root canal irrigating solutions and periodontal blood flow.

A drawback of this in vitro study is the lack of calcified canal, because it was difficult to find enough pulp calcification teeth to test the efficiency of guided endodontic treatment. The application of guide endodontics in calcified root canal has been reported in some clinical cases, and good therapeutic effects have been achieved [11, 20]. The use of guided endodontics in normally calcified teeth enables preservation of a significant amount of tooth substance [30]. The influence of pulp calcification on the efficiency of guided endodontics needs further studies.

Conclusions
With the limitations of this study, it may be concluded that the access cavity preparation performed with guided endodontics has feasible accuracy and low temperature rise on the root surfaces, indicating their high reliability and safety in clinical applications.

**Abbreviations**

RCT: root canal treatment; CBCT: cone-beam computed tomography; 3D: three-dimensions; STL: standard tessellation language; SD: standard deviation; CI: confidence interval; SD, standard deviation; M-D, mesial-distal direction; B-L, buccal-lingual direction.

**Declarations**

**Ethics approval and consent to participate**

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethical Committee Department of the Affiliated Stomatological Hospital of Nanjing Medical University (PJ2018-022-001). Written informed consents were acquired from all participants and/or their legal guardian for study participation.

**Consent for publication**

Not applicable

**Availability of data and materials**

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request. All data analysed during the current study are included in its supplementary information files.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

The work was supported by A Project Funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions (2018-87), the Scientific Research of Jiangsu Commission of Health (H2017050) and the Scientific Research Project of Health Care for Cadres of Jiangsu Province (BJ21034).

**Authors’ contributions**

CfZ, Conceptualization, Data curation, Formal analysis, Writing - original draft. XZ, Methodology, Data curation review & editing. CC, Investigation, Validation, Visualization.
Acknowledgments

The authors are grateful to the study participants.

References


Figure 1

Design and manufacture guided plates. (A): a virtual bur superimposed to the root canal in the design software; (B): the special designed bur; (C): interface of design software for guide plate; (D): a top view of the model and guided plate; (E): guided plate with metal sleeves positioned on the model, and a special designed bur and a diamond bur were put in the metallic sleeves.
Figure 2

Deviation measurement. (A): creating virtual bars in Magics software; (B): measurement diagram; (C): virtual bar in postoperative CBCT image; (D-E): the base of the measure point, red line in E represents the plane of D; (F-G), the tip of the measure point, red line in G represents the plane of F.
Figure 3

Study model of the temperature measurement and the marked position of the temperature sensor and the test instruments. (A): study model; (B): guided drill; (C): F3; (D): ET20.