Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth

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Abstract

Introduction: The aim of this study was to assess the accuracy of guided endodontics in mandibular anterior teeth by using miniaturized instruments. This technique is designed to treat teeth with pulp canal calcifications and narrow roots by using a printed template that guides a bur to the calcified root canal. **Methods:** Sixty sound mandibular anterior teeth were used in 10 mandibular models. Preoperative surface and cone-beam computed tomography scans were matched by using the coDiagnostix software. Virtual planning was performed for the access cavities, and templates were used for guidance. The templates were produced by a three-dimensional printer. Two operators performed the access cavities. A postoperative cone-beam computed tomography scan was superimposed on the virtual plan, and the deviation was measured in 3 dimensions and angles. Descriptive statistical analyses were performed, and 95% confidence intervals were calculated for both operators and each measured aspect. **Results:** The deviations between the planned- and prepared-access cavities were low, with means ranging from 0.12 to 0.13 mm for different aspects at the base of the bur and 0.12 to 0.34 mm at the tip of the bur. The mean of angle deviation was 1.59°. A considerable overlap of the 95% confidence intervals indicated no significant difference between the operators. The mean treatment time, including planning and preparation, was approximately 10 minutes per tooth. **Conclusions:** Microguided endodontics provides an accurate, fast, and operator-independent technique for the preparation of apically extended access cavities in teeth with narrow roots such as mandibular incisors. *(J Endod 2017;■:1–4)*

Key Words

Accuracy, guided endodontics, printed templates, pulp canal calcification, root canal treatment

Significance

Endodontic treatment of teeth with pulp canal calcifications is very challenging and associated with a high technical failure rate. Microguided endodontics provides an accurate technique for the preparation of access cavities and is therefore of high clinical relevance.

Pulp canal calcification (PCC) is a common sequela of dental trauma and may occur in 15%–40% of patients after luxation injuries (1, 2). In elderly patients, PCC may develop because of a lifelong apposition of the secondary and tertiary dentin (3). Furthermore, orthodontic treatment may initiate the accelerated deposition of secondary dentin (4, 5).

PCC is considered a sign of pulp vitality, and unless there is clinical and radiographic evidence of pulp necrosis, root canal treatment is not indicated (6).

However, up to one third of teeth with PCC may develop apical pathology in the long term (7). Root canal treatment is very challenging in these cases and is associated with a high failure rate, especially in mandibular incisors (8). Therefore, the American Association of Endodontists rated the treatment of teeth with PCC as having a high difficulty level (9).

Even with the use of a dental microscope, the preparation of an adequate access cavity may lead to excessive substance loss that impairs stability and thereby reduces the long-term prognosis of the tooth (10).

Recently, a new treatment approach for teeth with PCC by using a printed template with incorporated sleeves that guide the bur to the calcified root canal has been developed (11, 12). This technique provides an accurate access cavity and has already been used in the clinic (13–15).

In these studies, mainly maxillary teeth had been treated. The sizes of the burs used (diameter, 1.2–2.4 mm) are not suitable for the treatment of teeth with PCC and narrow roots such as mandibular incisors.

Therefore, the aim of this study was to assess the accuracy of guided endodontics in mandibular anterior teeth by using miniaturized instruments.

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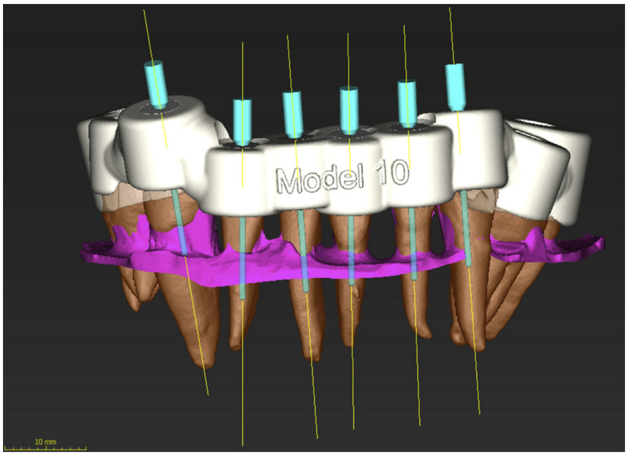

Figure 1. Virtual planning: 3D view of planned access cavities including burs and template.

Materials and Methods

Ten mandibular models were fabricated by using 100 sound human teeth that were extracted for periodontal reasons. Ethical approval was obtained from the local Research Ethics Committee (EKNZ UBE-15/111).

All teeth were fixed according to their anatomic position in a cast to mimic a partly dentate mandible with bilaterally missing molars. Mandibular incisors and canines (n = 60, 6 teeth per model) were used as test teeth, and premolars were included to improve the support of the printed template.

For each model, a preoperative cone-beam computed tomography (CBCT) scan with a voxel size of 80 μm was performed (Morita Accuitomo 80; J. Morita Mfg Corp, Kyoto, Japan) and stored in Digital Imaging and Communication (DICOM) format. In addition, surface tessellation language (STL-) files were created via a three-dimensional (3D) intraoral scanner (iTero; Align Technology Inc, San Jose, CA). Both types of data were uploaded to software that was originally designed for guided implantology purposes (coDiagnostiX Version 9.2; Dental Wings Inc, Montreal, Canada). Virtual images of the bur and the corresponding sleeve for access cavity preparation were designed and implemented in the software.

The specially designed bur had a total length of 28 mm with a working length of 20 mm, and the diameter was 0.85 mm (Gebr. Brasseler GmbH & Co KG, Lemgo, Germany). The sleeve had an inner diameter of 0.88 mm, an outer diameter of 4 mm, and a length of 6 mm (steco-system-technik GmbH & Co KG, Hamburg, Germany). Access to the root canal was planned by the superimposition of the virtual bur (Fig. 1). The position was checked in every 3D aspect. Then the virtual sleeve was placed. The STL data were uploaded to the same software, and scans were matched by aligning the outlines of the teeth. The template was designed via the application of an inbuilt tool and fabricated with a 3D printer (Objet Eden 260 V, Material: MED610; Stratasys Ltd, Minneapolis, MN). Subsequently, the sleeves were integrated into the template.

The 10 models were randomly assigned to 2 operators with 5 models (n = 30 teeth) per operator.

The fit of each template was checked on its dental model, and marks were set through the sleeves to indicate the exact coronal position of the access cavity. First, the enamel was removed with a diamond bur until the dentin was exposed. Next, the microguided bur was used at 10,000 RPM through the sleeve and the template with pumping movements to gain access to the root canal (Fig. 2). The bur was cleaned regularly during preparation by using a clean stand with foam rubber (Dentsply Maillefer, Ballaigues, Switzerland). The access cavity according to the virtual plan was finalized when the bur reached the sleeve. The bur was checked after every access cavity for deformation. If no deformation was visible, the bur was replaced regularly after 5 teeth.

The time required for each workflow step (surface scan of the whole model, virtual planning of the access cavity of each tooth, design of the template, removal of the enamel, and preparation of the access cavity) was recorded for each of the operators.

After completion of the access cavity preparations, a postoperative CBCT scan with the same parameters was performed, and DICOM data were uploaded to the coDiagnostix software. The preoperative and

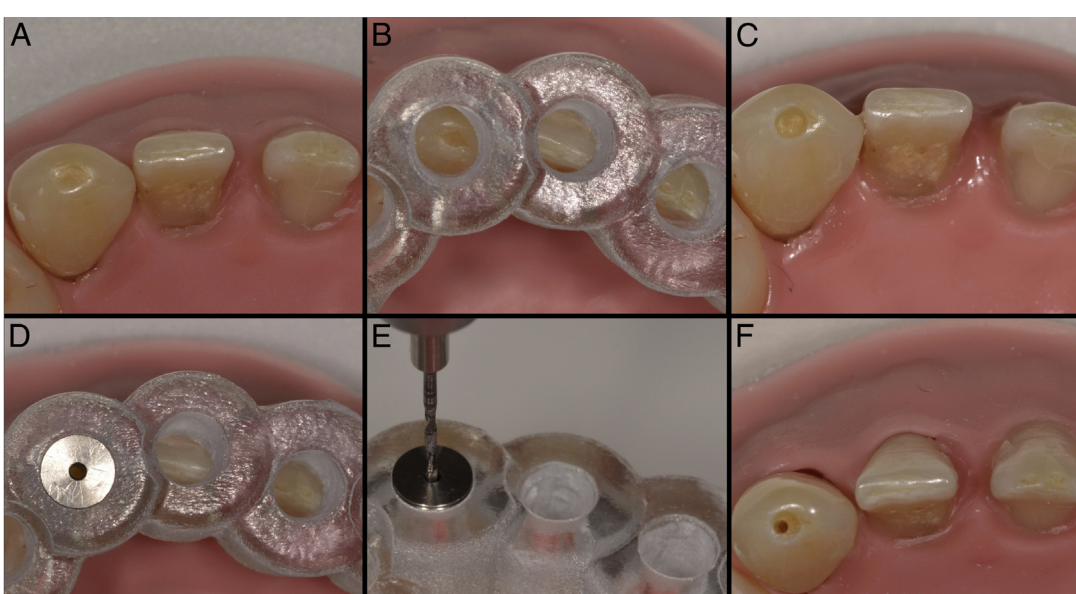

Figure 2. Clinical procedure for microguided endodontics: (*A*) preoperative situation, (*B*) adaption of the template, (*C*) removal of the enamel until the dentin is exposed, (*D*) template with incorporated sleeve, (*E*) guided preparation through the sleeve, and (*F*) access cavity according to planning.

TABLE 1. Times Required (Mean, Minimum, and Maximum) for Intraoral Scan, Virtual Planning of Access Cavity, Design of Template, Removal of Enamel, Preparation of Access Cavity, and Total Treatment in Seconds

	Surface scan	Virtual planning	Design template	Removal of enamel	Access cavity	Total treatment
Mean	271	58	235	19	30	613
Minimum	206	28	186	11	9	447
Maximum	340	122	303	31	208	936

postoperative CBCT scans were aligned, and the virtual planning was superimposed. This process allowed the software to automatically calculate the deviation between planned and performed access cavity preparations. Deviations were calculated at the base (coronal end point of bur's working length) and the tip of the bur in mesiodistal, bucco-oral, and apico-coronal directions.

A descriptive statistical analysis was followed by calculations of the mean of the absolute difference, the standard deviation, and the minimum and maximum of the deviation. The 95% confidence interval (CI) was calculated for each parameter and operator. Statistically significant differences were expressed by non-overlapping CIs. The analyses were conducted by using JMP 11 (SAS Institute Inc, Cary, NC).

One tooth had to be excluded because the alignment of preoperative and postoperative CBCT scans was not possible because of the loosening of the tooth in the model.

Results

The mean time required for a microguided endodontic treatment, including the surface scan, virtual planning, and access cavity preparation, was 613 seconds, with a range from 447 to 936 seconds. The preparation of the access cavity by using the guided endodontic technique required 30 seconds (mean), with a range from 9 to 208 seconds. The mean, minimum, and maximum for every procedural step are presented in Table 1.

The mean deviation of the angle was 1.59° (minimum, 0°; maximum, 5.3°). The mean of the absolute difference at the base of the bur in mesial/distal direction was 0.12 mm (range, 0–0.54 mm), and these values were 0.13 mm (range, 0–0.4 mm) and 0.12 mm (range, 0–0.41 mm) for the buccal-oral aspect and apical-coronal directions, respectively.

At the tip of the bur, the mean of absolute difference was 0.14 mm (range, 0–0.99 mm) for mesial/distal aspect, and these values were 0.34 mm (range, 0–1.26 mm) and 0.12 mm (range, 0–0.4 mm) for the buccal/oral and apical/coronal aspects, respectively. Table 2 summarizes the results of the accuracy measurements.

The 95% CIs of all measured parameters differentiated by operator are provided in Table 3. The considerable overlaps of all CIs indicated a lack of statistically significant differences between the operators.

None of the used burs fractured, and no perforations occurred.

Discussion

The results of this *ex vivo* study demonstrated that the presented microguided endodontics technique is an accurate, fast, and operator-independent tool for accessing root canals.

Although guided endodontics has been described before (11–14), this is the first study in which it was used on mandibular front teeth. This was possible because of miniaturized instruments with diameters of only 0.85 mm. Treatment of these small and very narrow teeth can be very challenging, and in cases of PCC, it is associated with a high technical failure rate of 71% (8). Therefore, a successful treatment depends on the technical accuracy of the access cavity.

With a mean angle deviation of 1.59° and a mean linear deviation of 0.12–0.34 mm from the apical target point in the present study, the method proved sufficiently accurate even for narrow roots such as mandibular incisors. The precision obtained with this approach seems to outperform that of navigation-guided procedures in oral implantology. A meta-analysis from 2009 presented a mean error at the apex of the implant of 0.85 mm (maximum, 4.5 mm) and a median angulation error of 4° (maximum, 20.43°) (16). A more recent meta-analysis reported even less accurate results, with mean errors of 1.12 mm at the entry point, 1.39 mm at the apex of the implant, and a mean angle deviation of 3.89° (17).

In contrast, better results with guided implants were obtained in a recent study that used the same setup as in the present investigation. This study adopted the coDiagnostix software and printed templates, and a comparable angle deviation of 1.5° was obtained. However, the mean apical deviation between the planned and inserted implant of 0.49 mm (0.13–1.19 mm) was higher than in the present study.

The less favorable results in guided implantology may be attributable to the fact that the template is occasionally only supported by mucosa, which might lead to an uncertain fit, and mucosal resiliency is another source of inaccuracy. Another reason could be that in contrast to guided endodontics, more than 1 bur is needed for implant site preparation.

Compared with the promising results already published for guided endodontics on maxillary teeth (11), which achieved a mean angle deviation of 1.81° and deviations of 0.17–0.47 mm at the tip of the bur, the accuracy was improved with the miniaturized approach of the present study. This improvement was achieved by optimizing the fit between the bur and the sleeve. A tight contact of the rotating bur to the sleeve inevitably leads to heat development, whereas a loose fit results in higher inaccuracies in angle.

TABLE 2. Deviations of Planned and Prepared Access Cavity at Base and Tip of the Bur

		Base of the bur			Tip of the bur		
	Angle (°)	Mesial-distal (mm)	Buccal-oral (mm)	Apical-coronal (mm)	Mesial-distal (mm)	Buccal-oral (mm)	Apical-coronal (mm)
Mean (absolute difference)	1.59	0.12	0.13	0.12	0.14	0.34	0.12
Standard deviation	1.22	0.12	0.12	0.12	0.18	0.28	0.11
Minimum	0	0	0	0	0	0	0
Maximum	5.3	0.54	0.4	0.41	0.99	1.26	0.4

Mean of the absolute difference, standard deviation, and minimum and maximum in the mesial-distal, buccal-oral, and apical-coronal directions (mm) as well as the deviation of the angle (°).

TABLE 3. Ninety-five Percent CIs (Standard Deviation) of All the Determined Parameters Differentiated by Operator

Parameter	95% CI	
	Operator 1 (M.Z.)	Operator 2 (T.C.)
Angle (°)	1.23–2.54	1.08–1.7
Mesial-distal (base) (mm)	0.07–0.17	0.08–0.16
Buccal-oral (base) (mm)	0.07–0.17	0.1–0.18
Apical-coronal (base) (mm)	0.06–0.15	0.09–0.18
Mesial-distal (tip) (mm)	0.08–0.24	0.07–0.18
Buccal-oral (tip) (mm)	0.21–0.5	0.25–0.4
Apical-coronal (tip) (mm)	0.07–0.14	0.09–0.17

Another study dealing with this topic used burs with diameters of 1.2 mm to prepare guided access cavities in 48 (unspecified) teeth *ex vivo* and resulted in a mean deviation of 0.46 mm (95% CI, 0.31–0.49) from the apical target point (12). This was considered acceptable; however, this deviation is slightly higher compared with the present results. Deviations in the preparation depth and angle were not measured. However, assessment of angle deviation is important because increasing the angle will result in greater deviation from the apical target point in long roots.

This study and the guided endodontics technique have limitations. First, this is an *ex vivo* study on teeth without complete calcifications. The influence of PCC on the accuracy remains unclear, and the time required to treat a tooth with PCC might be slightly longer than the treatments in this study. Clinical studies are desirable to add evidence regarding this technique. In addition, this technique is only practicable in straight roots or in the straight part of a curved root. Accessibility in molars with this technique might not be possible because of limited space for the template and the drill in the posterior region. The recorded time required for planning in this study seems reasonable, but a less experienced operator might need more time for all of the procedural steps. Nevertheless, conventional treatment of teeth with calcified root canals is likely to require much more operating chair time, which in turn is directly related to the cost of root canal treatment.

Additional costs associated with CBCT may arise anyway when treating cases with complex morphologies (eg, mandibular anterior teeth) or severe calcification as recommended both by the American Association of Endodontists (18) and the European Society of Endodontology (19).

Compared with an implant (when root canal treatment is not feasible or not successful), the total cost of the (micro)guided endodontics approach seems considerably lower.

Another critical point is the increased radiation dose that is due to CBCT. Although a limited field of view is sufficient for guided endodontics and the radiation doses of newer devices are decreasing (20), the dose remains higher than that of a conventional periapical radiograph.

Clinically, the presented treatment approach has already proven its worth. Three published case reports have demonstrated successful treatments of teeth with PCC *in vivo* by using templates to access calcified root canals (11, 14, 15).

In general, information about the treatment of teeth with PCC is rare. Conventional endodontic therapy has been demonstrated to be associated with a high failure rate, especially for lower front teeth (71%), which leads to a considerably decreased healing rate (8). Akkerblom and Hasselgren highlighted that teeth with PCC and preexisting periapical pathosis have a success rate of only 62.5%. A very recent study demonstrated that calcified root canals of elderly people are accessible if treated by an endodontic specialist under a dental microscope (21). The time needed to locate a root canal varied considerably and lasted up to 60 minutes in that study. However, no information about the loss of tooth substance associated with the access cavity preparation was provided. This aspect requires further investigation for both the conventional and the guided endodontics techniques.

Conclusions

Microguided endodontics provides an accurate, fast, and operator-independent technique for the preparation of apically extended access cavities in teeth with narrow roots such as mandibular incisors.

Acknowledgments

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The authors deny any conflicts of interest related to this study.

References

1. Nikoui M, Kenny DJ, Barrett EJ. Clinical outcomes for permanent incisor luxations in a pediatric population: III—lateral luxations. Dent Traumatol 2003;19:280–5.
2. Andreasen FM, Zhijie Y, Thomsen BL, et al. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. Endod Dent Traumatol 1987;3:103–15.
3. Foreman PC, Soames JV. Structure and composition of tubular and non-tubular deposits in root canal systems of human permanent teeth. Int Endod J 1988;21:27–36.
4. Delivanis HP, Sauer GJ. Incidence of canal calcification in the orthodontic patient. Am J Orthod 1982;82:58–61.
5. Bauss O, Rohling J, Rahman A, et al. The effect of pulp obliteration on pulpal vitality of orthodontically intruded traumatized teeth. J Endod 2008;34:417–20.
6. Holcomb JB, Gregory WB Jr. Calcific metamorphosis of the pulp: its incidence and treatment. Oral Surg Oral Med Oral Pathol 1967;24:825–30.
7. Oginni AO, Adekoya-Sofowora CA, Kolawole KA. Evaluation of radiographs, clinical signs and symptoms associated with pulp canal obliteration: an aid to treatment decision. Dent Traumatol 2009;25:620–5.
8. Cvek M, Granath L, Lundberg M. Failures and healing in endodontically treated non-vital anterior teeth with posttraumatically reduced pulpal lumen. Acta Odontol Scand 1982;40:223–8.
9. American Association of Endodontists. AAE endodontic case difficulty assessment and referral 2005. Available at: https://www.aae.org/uploadedfiles/publications_and_research/endodontics_colleagues_for_excellence_newsletter/ss05ecfe.pdf. Accessed February 2, 2016.
10. Lang H, Korkmaz Y, Schneider K, et al. Impact of endodontic treatments on the rigidity of the root. J Dent Res 2006;85:364–8.
11. Zehnder MS, Connert T, Weiger R, et al. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J 2016;49:966–72.
12. Buchgreitz J, Buchgreitz M, Mortensen D, et al. Guided access cavity preparation using cone-beam computed tomography and optical surface scans: an *ex vivo* study. Int Endod J 2016;49:790–5.
13. Krastl G, Zehnder MS, Connert T, et al. Guided endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. Dent Traumatol 2016;32:240–6.
14. van der Meer WJ, Vissink A, Ng YL, et al. 3D computer aided treatment planning in endodontics. J Dent 2016;45:67–72.
15. Krastl G, Krug R, Zehnder MS, et al. Guided endodontics: introducing a novel treatment approach for teeth with pulp canal calcification and apical pathology. Endodontie 2016;25:207–11 [Article in German].
16. Jung RE, Schneider D, Ganeles J, et al. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants 2009;24 Suppl:92–109.
17. Tahmaseb A, Wismeijer D, Coucke W, et al. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants 2014;29 Suppl:25–42.
18. AAE and AAOMR joint position statement: use of cone beam computed tomography in endodontics 2015 update. Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:508–12.
19. Patel S, Durack C, Abella F, et al. European Society of Endodontology position statement: the use of CBCT in endodontics. Int Endod J 2014;47:502–4.
20. Ludlow JB, Timothy R, Walker C, et al. Effective dose of dental CBCT: a meta analysis of published data and additional data for nine CBCT units. Dentomaxillofac Radiol 2015;44:20140197.
21. Kiefner P, Connert T, ElAyouti A, Weiger R. Treatment of calcified root canals in elderly people: a clinical study about the accessibility, the time needed and the outcome with a three-year follow-up. Gerodontology 2016. Jun 14; http://dx.doi.org/10.1111/ger.12238 [Epub ahead of print].