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ORIGINAL ARTICLE

Accuracy of an endoscope to detect root canal anastomoses in mandibular molar teeth: a comparative study with micro-computed tomography

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ABSTRACT

Objective: The aim of this study was to investigate the accuracy of endoscopic visualization to detect root canal anastomoses at the coronal half of the mesial root canals of mandibular molars using micro-computed tomographic (micro-CT) images as reference.

Material and methods: Seventy-four mesial roots of mandibular first molars with ($n = 47$) or without ($n = 27$) intercanal anastomosis were selected based on the micro-CT scans of 269 mandibular first molars at a pixel size of 10 µm. The specimens were mounted on the mannequins and their root canals were evaluated using dental operating microscope (DOM) and endoscope. The endoscopic probe was inserted into the main mesial root canals and 2 blinded observers evaluated the presence of a divergence point of anastomosis (where the branching occurs) as 'present' or 'absent'. The scorings were compared with the three-dimensional reconstructed images of the specimens and recorded as 'correct' or 'incorrect' evaluation. Degree of agreement between evaluators was assessed with Kappa test and the accuracy of endoscopic visualization according to the presence and location of anastomosis was compared using Fisher exact tests with a significance threshold at 5%.

Results: High inter-examiner reliability was reported (0.91). None of the divergence points were identified using DOM whereas 11 divergence points were detected using endoscope, corresponding the 23.4% of the intercanal anastomoses. The endoscope also showed the absence of an intercanal anastomosis correctly in all of the specimens without an anastomosis. Detectability of a divergence point using endoscope was not affected by its location within the coronal half of root canal ($p > .05$).

Conclusions: The endoscopes were able to visualize the divergence points of 23.4% of the intercanal anastomoses located at the coronal halves of root canals.

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Introduction

Root canal treatment aims to prevent or treat apical periodontitis by disinfecting the root canal system through cleaning and shaping of root canals to an adequate geometry [1]. However, the complexity of root canal configurations showing accessory root canals, isthmuses, and anastomoses poses a major challenge for clinicians in fulfilling the goals of root canal treatment [2–4]. Failure to diagnose and treat entire root canal system might result in the presence of microorganisms and their toxins within the root canal system and lead to persistent apical periodontitis [5].

Anastomosis accessory canal was described as a narrow connection between two canals according to a recent micro-computed tomography (micro-CT) study [6]. These canals are common in the mesial roots of mandibular molars [7–9]. Another micro-CT study reported that anastomosis accessory canals were detected in 20.5% of coronal and 19.4% of middle thirds of mesial roots of mandibular molars [10].

In clinical conditions, diagnosis of anastomoses in mandibular molars is particularly challenging since they are located between two superimposing main mesial canals in periapical radiographs [11]. Cone-beam computed tomography (CBCT) is useful however not applicable during treatment. Moreover, CBCT has been reported to fail to show fine anatomical structures accurately and subdiagnose anatomical variations [12]. Endoscopic visualization is a safe magnification and examination technique that does not involve X-ray radiation [13]. Endoscopes have been developed for *in vivo* use to visualize root canal anatomy during orthograde endodontic treatment [14]. Several studies showed that endoscopes could provide magnified view of pulp chamber, detect fracture lines and visualize apical foramen and accessory canals [14,15] however according to the authors' knowledge no study compared the accuracy of the endoscope to detect anastomoses using gold standard micro-CT images. The aim of this study was to evaluate the accuracy of endoscopic examination of root canal anastomoses by visualization of their divergence points where they leave the main root canal, at the coronal half of the mandibular molar mesial roots by comparing to micro-computed tomographic (micro-CT) images.

Material and methods

Micro-CT scanning and specimen selection

The study protocol was approved by local university ethical board for clinical studies (KAEK 2015/408). A total of 74 mesial roots of mandibular first molars with ($n = 47$) or

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without ($n = 27$) intercanal anastomosis at their coronal halves were selected after scanning 269 mandibular first molar teeth using micro-CT (SkyScan 1172; Bruker-microCT, Kontich, Belgium) at a pixel size of 10 µm. Patient gender and age were unknown. Slices presenting 2000 × 1330 pixel resolution were obtained from each root using an 11 MP camera. Data were reconstructed using NRecon software (v.1.6.4, Bruker-microCT) with a beam-hardening correction of 45%, smoothing of 2, and an attenuation coefficient range of 0–0.06. CTAn (v.1.18.8, Bruker-microCT) and DataViewer (v.1.5, Bruker-microCT) software were used to reveal the root canal configuration of each root.

The presence, number and location of each anastomosis were recorded for both mesiobuccal and mesiolingual canals. Three-dimensional reconstruction image of each specimen was included to the recordings. A single operator performed the selection of the specimens and recordings (A. K.).

Preparation of the specimens

Coronal halves of MB and ML were enlarged using the SX instrument of the ProTaper Universal rotary system (Dentsply Sirona, Ballaigues, Switzerland) for endoscopic visualization. The root canals were flushed with 5 mL of 5.25% NaOCl, distilled water and 17% EDTA for 1 min, respectively. Coronal enlargement was performed by a single operator who was blinded to the root canal configurations (C. K.). The specimens were placed in dentaforms and mounted in mannequins (Frasaco GmbH, Tettnang, Germany) to simulate clinical conditions as closely as possible for microscopic and endoscopic visualization.

Dental operating microscopic (DOM) visualization

Each mesial root canal was inspected using a DOM with 10x/16 mm eyepiece, 5 (2.5x) knob position and 80-W light emitting diode (LED) light source (Densim microscope, Diplomat Dental s.r.o., Piestany, Slovak Republic). Two independent evaluators who were blinded to the three-dimensional root canal configuration of the specimens (R. A. & C. K.) utilized DOM to examine root canal walls regarding the presence of divergence point of anastomosis from main canals. The presence or the absence of the divergence point was recorded.

Endoscopic visualization

The endoscopic device included a 15-inch liquid crystal display thin film transistor monitor with LED backlight with 1024 × 768 resolution (Karl Storz GmbH & Co. KG, Tuttlingen, Germany), camera head (Karl Storz, Germany) and telescope with 0.5 mm outer diameter and 0 degree viewing angle (Karl Storz, Germany). Endoscopic evaluation was performed by 2 independent evaluators who were blinded to the anatomy of the specimens (R. A. & C. K.). The specimens were stabilized in dentaforms mounted in mannequins. The telescope was inserted into the coronal halves of the MB and ML canals. The presence or the absence of the divergence point of an anastomosis was evaluated by the inspection of the image reflecting on the monitor of the endoscopic unit while the telescope was progressing within the coronal half of the canals in coronal to apical direction. The insertion depth of the telescope was controlled by a rubber stopper. The examiners were asked to assess the endoscopic image for each level during scoping. At each milimeter the telescope was stopped and the image of the screen was evaluated. The scoring was recorded, as a divergence point was 'present' or 'absent'.

Statistical analysis

The evaluators were given the reconstructed micro-CT images and data sheets. The results for endoscopic evaluation were compared with micro-CT images and data to determine the accuracy of the endoscopic evaluation scorings of the evaluators. The endoscopic scoring results were recorded as 'correct' or 'incorrect' after comparing with micro-CT images as reference. The level of each anastomosis divergence was classified according to their distance from the coronal surface of roots as 1, 2 and 3 mm. Inter-examiner reliabilities for each assessment were verified by Kappa test. Scores obtained from the comparison of endoscopic visualizations with the micro-CT analysis according to the location of divergence points were analyzed by using Fisher's exact tests. Statistical analyses were performed by SPSS software (SPSS Inc, Chicago, IL, USA), with a level of significance set at 5%.

Sensitivity, specificity, positive and negative predictive values and accuracy were calculated for endoscope taking into account the micro-CT images (MedCalc software, Mariakerke, Belgium). Sensitivity was the proportion of specimens with intercanal anastomosis that were correctly detected by endoscope (true positive rate). Specificity was the proportion of the specimens without intercanal anastomosis that were correctly diagnosed as not having one (true negative rate). Positive predictive value was the probability that actually there was divergence point when the endoscope detected a divergence point. Negative predictive value was the probability that there was no divergence point when the endoscopic evaluation indicated there was none. Finally, accuracy was the proportion of correct detection of presence or absence of anastomosis.

Results

None of the divergence points were detectable *via* DOM according to both evaluators. During endoscopic evaluation, evaluator A scored 10 root canals with anastomosis correctly, whereas evaluator B scored 11 of them correctly (Table 1). Both examiners scored the absence of an anastomosis *via* endoscope correctly in all inspected root canals. The Kappa values in the evaluation of endoscopic images indicated a high level of agreement between the evaluators (0.91). Representative images of the divergence points acquired from endoscopic visualization are shown in Figure 1. Fisher's exact test showed that detectability of an anastomosis

Table 1. Number of divergence points detected by endoscopic examination compared to the reference micro-CT images according to their locations.

	Examiner A		Examiner B	
	Correct	Incorrect	Correct	Incorrect
Without anastomosis	27^{a}	0^{a}	27^{a}	0^{a}
Anastomosis within 1 mm	3^{b}	15^{b}	4^{b}	14^{b}
Anastomosis within 2 mm	7^{b}	19^{b}	7^{b}	19^{b}
Anastomosis within 3 mm	0^{b}	3^{b}	0^{b}	3^{b}
Total	37	37	38	36

Different superscript letters in the same column means statistically significant difference ($p < .05$).

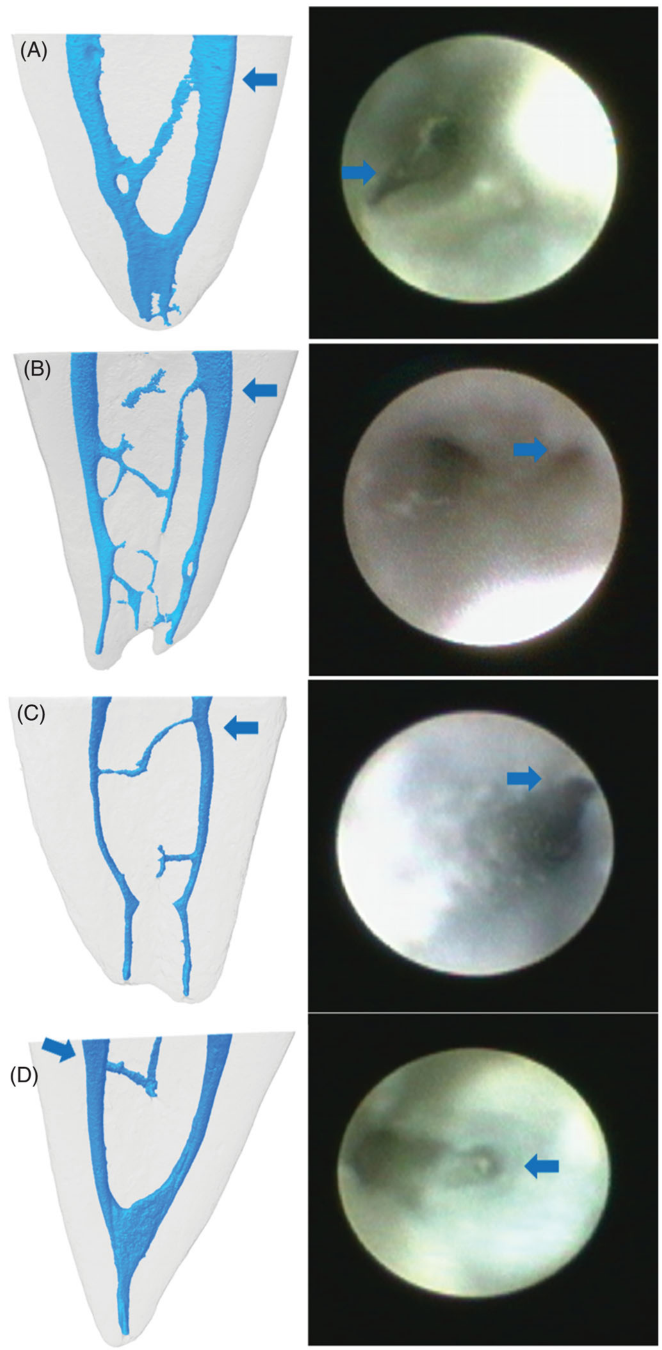

Figure 1. (A–D) Micro-CT reconstructed images of 4 specimens showing coronal anastomosis branching from main mesial root canals. Right column depicts the endoscopic images of the same specimens obtained during endoscopic visualization. Arrows in the centre images depict direct visualization of the divergence points by endoscopic imaging.

Table 2. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy values for endoscope to diagnose divergence points (%).

	Value	95% Confidence interval
Sensitivity	21.28	10.70 – 35.66
Specificity	100	87.23 – 100.00
PPV	100	–
NPV	42.19	38.61 – 45.85
Accuracy	50.00	38.14 – 61.86

divergence *via* endoscopic visualization was not significantly influenced by their location ($p > .05$; Table 1).

Table 2 presents the sensitivity, specificity, predictive values and accuracy of the endoscope. Endoscope exhibited a poor sensitivity (21%) and high specificity (100%) values for the detection of divergence points.

Discussion

The presence of a root canal anastomosis in mandibular molars cannot be diagnosed by preoperative periapical radiographs due to their superimposition with the remaining mesial root canals [11]. Three-dimensional imaging techniques constitute the most effective methods for detecting actual internal root canal anatomy [10]. Computed tomography devices combine X-ray and computer technology and allow for three-dimensional visualization of scanned objects *via* different cross-sections. Micro-CT emerged as the most accurate technique to reveal the internal anatomy of different root canal configurations due to the production of high-resolution images [9–11]. This technology allows the practitioner to make qualitative and quantitative measurements of the shape, volume and dimensions of root canal anatomy without destroying the specimens [10,11]. However, micro-CT is not suitable for *in vivo* use. On the other hand, CBCT has been reported to provide limited information regarding the fine structures of root canal system [12]. CBCT has been reported to detect the presence of isthmuses accurately in 65% of the cases and lead to a subdiagnosis of the complex root canal anatomy [12,16]. In the future, more detailed visualization of root canal structures may be obtained by increasing the spatial resolution of CBCT devices; however, discussions on radiation containment will continue to be a topic of debate.

In the present study, none of the anastomoses were detected *via* DOM. DOM is a valuable diagnostic and operative tool for the diagnosis of root canal orifices and detection of accessory canals, vertical cracks, broken instruments, or residual root canal filling materials within root canals [17,18]. Mesial root canals of mandibular molars show curvature to converge towards each other while extending apically. In the present study both endoscopic and micro-CT images showed that root canal anastomoses originate from lateral inner wall of mesial root canals adjacent to the developmental groove. Visualization of the anastomoses using DOM might be prevented by inability of the microscope light to reach the lateral inner walls, which the anastomoses are originated from. Visualising of the lateral canal walls and detection of any detail such as anastomosis or ishtmus by microscope would not be possible due to staying out of sight of focussing of the DOM.

The efficacy of DOM to visualize the components of root canal configuration depends mainly on the operator experience [19]. The use of DOM requires a preparation and training prior to effective use particularly in mandibular molars, because adjustment of microscope light to reach lateral root canal walls is limited by the surrounding tissues, walls of the access cavity and inclination of root canals [19]. The orthograde use of endoscope in endodontics is relatively novel. Limited number of studies investigated its possible indications using few commercially available endoscopes; however, advantages and limitations of this technique have not yet been throughly studied [20,21]. In the present study, endoscopic evaluation detected 23.4% of the divergence points of the anastomosis located in the coronal half of root canals. Still, the telescope of the endoscope could not be able to provide a lateral view of the root canal walls. The telescope has a stainless steel sheath to protect fibre bundles resulting a semirigit structure [22]. This semirigit structure limits the penetration of the telescope to reach beyond the curvature of root canals. In the present study the outer diameter of the telescope was 0.5 mm, currently known as one of the thinnest telescopes. In medical endoscopic devices that are used in broader organs, the tips enable the visualization of the lateral sides of the inspected organ, however the contemporary telescope does not have this ability, yet [22]. Development of the endoscope to increase the flexibility and resolution rate, would undoubtedly increase the *in vivo* direct visualization of fine structures of root canal system and improve root canal treatment outcome predictability.

The present study showed that endoscopic examination might reveal the presence of divergence points of the anastomoses on the root canal walls of main mesial canals however it did not provide information on how these branchings navigate through roots; either as an anastomosis connecting between main canals or independent accessory canals with their own apical foramina. Previous micro-CT studies considered root canal structures branching from main mesial canals, extending and terminating apically as middle mesial root canals with no orifices [4,23]. Their relatively smaller size and volume render these structures difficult to locate and negotiate during root canal treatment. Troughing between main mesial canal orifices with 2 mm depth and 1 mm diameter is suggested to eliminate dentinal irregularities and increase the detection rate of these structures [24]. A recent micro-CT study reported significantly thinner distal dentine walls of middle mesial root canals creating a danger zone [25]. Overall, troughing means loss of sound dentinal structure in the danger zone; unnecessary troughing must be averted [24–26].

The use of 3 D images obtained *via* micro-CT for the testing of the endoscope is important for the reliability of the results obtained. The endoscope has the potential for the development of techniques for the direct visualization of internal root canal anatomy without harming the patient. In the present study, endoscopes indicated a high specificity to detect the absence of a divergence point. However, the accuracy of the endoscope is currently limited by restricted flexibility and 0.5 mm telescope diameter, which is relatively wider than apical root canal dimensions. In addition, remaining hard tissue debris might cover divergence opening of anastomosis leading to an increase in false negative results. More research is warranted not only to develop endoscopes for more specific usage in endodontics but also to investigate the ability of endoscopes to visualize the internal anatomy of the root canals *in vivo*.

Conclusion

Within the limitations of the present study, divergence points located on the inner wall of main mesial root canals were undetectable under magnification *via* DOM, while endoscopic examination could detect 23.4% of them at the coronal halves of canals.

Disclosure statement

The authors deny any conflicts of interest.

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