Impacts of contracted endodontic cavities compared to traditional endodontic cavities in premolars

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Research article

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Abstract

Background: This study aims to compare the percentage of dentin removed, instrumentation efficacy, root canal filling and load at fracture between contracted endodontic cavities, and traditional endodontic cavities on root canal therapy in premolars.

Methods: Forty extracted intact human first premolars were imaged with micro-CT and randomly assigned to the contracted endodontic cavity (CEC) or traditional endodontic cavity (TEC) groups. CEC was prepared with the aid of a 3D-printed guiding template, canals were prepared with a 0.04 taper M-Two rotary instrument, and cavities were restored with resin. The specimens were loaded to fracture in an Instron Universal Testing Machine after a fatigue phase. The data were analyzed by the independent samples T test and Mann-Whitney U test, appropriate post hoc tests.

Results: In the premolars tested in vitro, the percentage of dentin removed in the premolars with two dental roots in the CEC group (3.85% ± 0.42%) was significantly smaller ($P < 0.05$) than in the TEC group (4.94% ± 0.5%). The untouched canal wall (UCW) after instrumentation for TECs (16.43% ± 6.56%) was significantly lower ($P < .05$) than the UCW (24.42% ± 9.19%) for CECs in single-rooted premolars. No significant differences were observed in the increased canal volume and surface areas in premolars between the TEC and CEC groups ($P > 0.05$). CECs conserved coronal dentin in premolars with two dental roots but no impact on the instrument efficacy, the root canal filling or the biomechanical responses was observed. There were no differences between the CEC groups and the TEC groups in the percentage of filling material and voids ($P > 0.05$). In addition, the mean load at failure of premolars did not significantly differ between the CEC and TEC groups and there was no significant difference in the type of fracture ($P > 0.05$).

Conclusion: The results of this study suggest that CEC could not improve the fracture resistance of the endodontically treated premolars. The instrumentation efficacy and the percentage of filling material did not significantly differ between CECs and TECs in the premolars.
Keywords: 3D-printed template, contracted endodontic cavities, instrumentation efficacy, root canal filling, fracture resistance

Background

Endodontic treatment is a procedure that consists of several steps aiming to retain the normal function of the treated tooth or prevent or heal the periapical periodontitis [1]. The principle of access and coronal cavity preparation is the straight-line pathways into root canals to enhance instrumentation efficacy and prevent complications [2, 3]. The treatment associated loss of tooth structure could undermine the biomechanical responses of the tooth [4],especially in endodontically treated teeth [5].

Today, materials and novel concepts, including the development of nickel-titanium instruments and the concept of minimally invasive endodontics (MIE), are rapidly changing. MIE is characterized by “systematic respect for the original tissue” and “preventing or treating disease with as little loss of original tissue as possible [6]. Contracted endodontic cavities (CECs), which were inspired by the concepts of MIE, emphasize endodontically treated tooth structure preservation, including pericervical dentin (PCD). The preservation of PCD is important for dental structure and is associated with a long-term survival benefit [7].

Three-dimensional (3D) printing is widely used for preoperative planning and procedure rehearsal [8], orthognathic surgery [9], custom prosthetic design [10], and surgical guidance and educational tool for teaching and to enhance communication between the patient and doctors [11]. 3D printing technology could achieve precise design, positioning, and good communication before the operation. The accuracy and safety of the 3D printed template have been proved [14, 15]. Therefore, this technology has been applied in a clinic more extensively to achieve good treatment outcomes [12, 13], besides the accuracy and safety for 3D printed template have been proved [14, 15]. This research was aimed to design the 3D printed template for endodontic cavities and explore the clinical significance of 3D printed template in endodontics.

Contracted endodontic cavities (CECs), as an alternative to traditional endodontic cavities, have been researched widely. So far, the outcomes and fracture resistance of CECs on root canal preparation still limited and controversial. Some literature had reported that the mean load at failure for CECs does not differ significantly from TECs in maxillary molars [16]. The type of access cavity does not influence the amount of remaining pulp tissue in root canals and isthmus in maxillary first molars [17]. Similarly, TECs lead to better preservation of the original canal anatomy in maxillary first permanent molars [18]. Most of the previous researches were focused on the efficacy of CECs and TECs treatment in maxillary molars. However, the efficacy of CECs and TECs treatment in premolars has been rarely investigated. The premolars is also very important in our mouth. Premolars are the concentration of occlusal and masticatory forces in the oral cavity, premolars undergoes and bears when in function.

In this study, systemic measurement, including, the percentage of dentin removed, instrumentation efficacy, the increased canal volume and surface areas, the increased sectional area, the percentage of the filling material, and fracture resistance of premolars was conducted.

Methods

Selection of teeth

The present study was approved by the Ethics Committee of the Hospital of Stomatology, Guangzhou Medical University (number KY2017012). Human first premolars from an orthodontic tooth extraction in the oral and maxillofacial surgery department were collected extracted. Informed written consent was obtained from each patient. Soft and hard tissue residuals on the surfaces of the teeth were removed using an ultrasonic scaler. All teeth had a fully formed apex without any defects or cracks on the surface and had no history of restoration. A curvature of 0–20°, according to Schneider [19] on buccolingual and mesiodistal radiographs was selected. The selected teeth were of similar dimensions. There was no statistically significant difference ($P>0.05$) in BL, MD, or tooth root length between the CEC and TEC groups. The teeth were kept in 1% chloramine T trihydrate at room temperature until use.

Manufacture of 3D-printed splint guide

The guided access cavity was prepared using cone-beam computed tomography and optical surface scans. A high-resolution cone-beam computed tomography (CBCT) scan was taken to determine the exact location of the root canal. The drill was virtually superimposed on the root canal to plan the CEC outlines by projecting the access trajectory in each canal orifice that required the least tooth structure removal in Simplant (SIMPLANT, Materialise Dental, Leuven, Belgium) (Fig. 1). The data were then imported into Freeform (Geomagic Freeform, 3D Systems, Morrisville, North Carolina, USA). According to the location of the drill in Simplant, we made a guide template with straight-line pathways into the tooth canal. Besides, we also designed a 3D printed cylindrical lampstand with a 0.2 mm gap to simulate the periodontal ligament for every specimen. The digitally designed template and 3D printed cylindrical lampstand were exported as STL-file and then were sent to a 3D printer (3D System 3510HB, 3D Systems, Morrisville, North Carolina, USA).

TEC and CEC preparation

First of all, the teeth were imaged with micro-CT (SkyScan 1172; Bruker micro-CT, Kontich, Belgium) imaging at 20 μm (pretreatment scan) to capture the original canal shape and volume of tooth tissue. In CEC preparation, a 3D-printed template was positioned on the tooth model (Fig. 1), and a guiding sleeve was placed on the hole. CECs were drilled with long diamond burs (MANI SF–11, MANI INC, Japan) at high speed. The CEC access attested the distal and mesial accesses could be directed towards their respective orifices, which kept back the truss of dentin between the cavities. In the TEC group, conventional access cavities were prepared. After initial preparation with pathfile instruments (Dentsply Maillefer, Ballaigues, Switzerland), canals were prepared with 0.04 taper M-Two rotary instruments (VDW company, Munich, Germany) to size 35#. These instruments were used in a standard technique, The canals were irrigated with 3 ml of 5.25% sodium hypochlorite (Guangzhou Hui Fan company, Guangzhou, China) between use of each instrument, and then, each canal was irrigated with 5.25% sodium hypochlorite followed by irrigation for 30 seconds with ultrasonic oscillation tip (K15/21–25, SATELEC, France) coupled with an ultrasound device (SATELEC P5XS, Merignac, France) at power 7. After cleaning and shaping, the teeth were imaged again with micro-CT imaging at 20 μm (posttreatment scan) to capture the instrumented canal shape and volume of tooth tissue for comparative the differences. All canals were obturated with gutta-percha cones (Dentsply Sirona, New York, Pennsylvania, USA) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany). The thermoplastic continuous wave of condensation technique was used for obturation using a B&L-beta Gutta Percha Heating System (B&L Biotech, Inc, Korea). Smart Dentin Replacement (Dentsply, DE, USA) was used to imitate the lost dentin tissue, and 2 mm composite resin restorative material (SHOFU, Kyoto, Japan) was placed on the canal opening. The teeth were stored in physiological saline at 37°C for one week. After that, each specimen was subjected to micro-CT imaging at 20 μm (finished scan).

Load at fracture

After root canal filling and micro-CT scanning, teeth with a 3D printed cylindrical lampstand were mounted in an Instron Testing machine (E3000, Instron, High Wycombe, UK). The specimens were subjected to 500000 loading cycles in the Instron Testing machine (E3000) axial forces, directed at a 135 angle from the long axis of the tooth [20], between 5 N–50 N at 15 HZ to simulate approximately 2 years of chewing function [21,22]. After this fatigue phase, the specimens were placed in the Instron Universal Testing machine (E3366, Instron, MA, America). Each tooth was loaded at the central fossa at 135° from the tooth long axis to simulate a maximum bending motion of the tooth at buccal cervical areas [9]. A continuous compressive force was applied with a 2-mm spherical crosshead at 1 mm/min until failure occurred, which was defined as a 25% drop in the applied force [23](Fig. 2A).The load at fracture was recorded in Newton (N), and the type of fracture was recorded (Fig. 2B).

Evaluation methodology

Canal and crown boundaries were demarcated at the buccal-lingual level of the cementoenamel junction in single-rooted premolars, and canal boundaries were demarcated in root separation in premolars with two dental roots. After reconstruction with NRecon (Bruker micro CT, Kontich, Belgium) software, the volume of the tooth tissue was analyzed with CT-AN software (Bruker micro CT, Kontich, Belgium), we selected appropriate CT value as the segmentation of tooth volume. After the pretreatment scan and post-treatment scan were aligned in Data Viewer software (Bruker micro CT, Kontich, Belgium), the increased canal volume and surface areas after root canals shaped during the two different access opening procedures were measured using CT-An software. The proportion of untouched canal wall (UCW) in the canals was determined with 3-Matic (Fig. 3), and we measured the sectional section of 1, 3, and 5 mm from the apical and the deviation of the central point in Solid Work (Dassault, France) (Fig. 4). The percentage volume of root filling materials and any voids inside the region of interest were calculated in CT-An software, and all areas without filling within the root canal space were considered voids, all analyses were calculated separately for the cervical, middle, and apical thirds of the canal.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics 16 software (Armonk, NY, USA), it was compared with independent samples T-tests, and the Mann-Whitney U test, $P < .05$ was considered significant.

Results

The percentage of dentin removed in the premolars with two dental roots in the CEC group (3.85% ± 0.42%) was significantly smaller ($P < 0.05$) than in the TEC group (4.94% ± 0.5%). The percentage of dentin removed has no significant differences ($P > 0.05$) between the TECs (3.4%±0.13%) and CECs (2.98% ± 0.12%) in the premolars with one dental root. The UCW after instrumentation for TECs (16.43% ± 6.56%) was significantly lower ($P< 0.05$) than the UCW (24.42% ± 9.19%) for CECs in single-rooted premolars. The UCW in premolars with two canal roots did not differ significantly ($P > 0.05$) between the TEC (21.28% ± 8.91%) and CEC (18.62% ± 5.85%) groups (Table 1). No significant differences were observed in the increased canal volume and surface areas in premolars between the TEC and CEC groups ($P > 0.05$). In the premolars with two dental roots, the increased sectional area of 1, 3, and 5 mm from the major apical foramen was significantly greater ($P < 0.05$) in the CEC group than in the TEC group. The deviation of the central point after instrumentation for TECs was significantly smaller ($P < 0.05$) than that for CECs. There was no significant difference ($P > 0.05$) between the TEC and CEC groups in the increased sectional area and the deviation of the central point in single-rooted premolars. Micro-CT analysis revealed that there were no differences between the CEC groups and the TEC groups in the percentage of filling material and voids ($P > 0.05$) (Table 2). In general, the mean load at failure of premolars did not significantly differ between the CEC and TEC groups, and there was no significant difference in the type of fracture ($P > 0.05$) (Table 3).

Discussion

Endodontics is moving forward to minimally invasive endodontics, including contracted endodontic cavities and periapical microsurgery. Technological advances such as CBCT imaging, operating microscopes, nickel-titanium instruments, and Single-Cone Technique provided a great deal of convenience. The contracted endodontic cavity may lead to difficulty in operative procedure due to smaller operating space, and have the potential to cause apical transportation, ledge or shelf and instrument fracture in consideration of the curvature inside root canals. This study suggested that apical transportation after instrumentation for CECs was significantly bigger ($P < 0.05$) than TECs in the premolars with two dental roots, and no instrument fracture was experienced. This means although the apical transportation of CECs was bigger in premolars with two dental roots, with the appropriate straight path to a root canal, there is a small probability that instrument fracture occurred in premolars. There was no significant difference ($P > 0.05$) between the TEC and CEC groups in the increased sectional area and the deviation of the central point in single-rooted premolars. Which means in single-rooted teeth, it is safe and effective.

It is reported that guided endodontics printed templates have been used to locate all root canals in the apical third of teeth with pulp canal calcification and apical pathology with the aid of 3D printing technology and digital dentistry [15,24]. In this research, we used guided endodontics printed templates for minimal cavity access, which acquired the least tooth structure removal and projected the access trajectory to each canal orifice. Contracted endodontic cavity with the aid of 3D-printed template seems to be a safe, clinically feasible method for locating root canals.

A previous study reported that CEC seems to exhibit better preservation of the original canal anatomy, particularly at the crown level, including incisors, premolars, and molars with TECs [23]. The conservative endodontic cavity, which could keep back the truss of dentin between the cavities, could save more dental tissue in premolars with two dental roots. Although more tooth tissue was retained, there was no obvious increase in the fracture resistance. It is probably because the volume of premolars was small, although CECs could conserve more corona dentin, and dental cervix dentin and the load at fracture for premolars with CEC was bigger than TEC. It couldn’t lead obvious statistical differences, and more data need to be studied.

The complete cleanness of the root canal was still the primary objective for nonsurgical root canal therapy. On the basis of the experimental data, the instrumentation efficacy was more effective for TECs than for CECs in single-rooted premolars. Because contracted endodontic cavities are smaller than traditional endodontic cavities, the instrument could not shape the entire wall of the canal into a straight line. With the aid of the 3D printed template and the straight line of contracted endodontic cavities, the instrumentation efficacy of TECs and CECs showed no significant difference in premolars with two canal roots ($P > 0.05$). According to the report [25], the instrumentation efficacy did not differ significantly ($P > .15$) between CECs and TECs in any of the roots or canal levels in maxillary molars. Another research found there was no significant difference in remaining pulp tissue between the TEC and CEC groups within the MB or ML root canal at any of 1/3 of the root [20].

In the premolars with two dental roots, the increased sectional area was significantly bigger ($P < 0.05$) in the CEC group than in the TEC group. It might be due to the design of canal orifice in the premolars with two dental roots. The drill was virtually superimposed on the root canal with inclination angle in the corona. When we design a straight-line pathway into canals, the orifice would be in the buccal cusp. Therefore, we shifted a little toward the middle to avoid the destruction of marginal ridges. Because of the inclination angle in coronal, the deviation of the central point after instrumentation for CECs was more significant ($P < 0.05$) than that for TECs. Mario A et al. also reported that TECs show more preservation of the original root canal anatomy with less apical transportation than CECs [21].

Micro-CT allowed the 3D anatomy assessment of root canal fillings and voids, and the results obtained in our study did not show obvious differences in the percentage of root canal filling in the CEC and TEC groups. Although the entrance of the pulp chamber is smaller in CECs, with the straight-line pathways into canals, the root canal filling can be completed for both CECs and TECs equally.

Numerous studies provided CEC preparation did not increase the fracture strength of teeth compared with TEC preparation [25–27]. This result corroborate with those above research. The researchers have found the endodontic procedures do not weaken teeth with intact marginal ridges [28],the CEC and TEC groups were both prepared with intact marginal ridges, and there were no significant differences ($P > 0.05$) on biomechanical responses between the premolars in the CEC and TEC groups. At the same time, the result was opposite to Krishan’s research [29], which reported CEC increased fracture resistance in premolars and mandibular molars. The following 4 explanations clarify this contradiction: (1) the simulated clinical treatment procedure to restore the access cavities with resin before fracture resistance test; (2) the angle of the tooth loaded at the central fossa from the tooth long axis and the spherical crosshead was different in this study; (3) single-rooted premolars and premolars with two dental roots were differentiated; (4) each sample has been tested by fatigue cycle test. All of these factors have a potential effect on the final results. In addition, the load type was comparable to that experienced in the mouth, and human teeth were subjected to forces in different directions at the same time, the tested teeth have irregular shapes, and the experimental data acquired were just in one direction, and the results were for reference. Besides, when we talk about CECs, the extended preparation time and materials should be considered.

Conclusion

Within the limitations of this study, the current results did not show obvious benefits associated with the CEC group compared with the TEC group. Although CECs could conserve more tooth hard tissue, the results of this study did not suggest that CEC could improve the fracture resistance of the endodontically treated premolars. The instrumentation efficacy and the percentage of filling material did not significantly differ between CECs and TECs in the premolars. Future experiments with bigger sample sizes and long-term clinical studies are encouraged to carry out on this topic. Besides contracted endodontic cavity with the aid of 3D-printed template seems to be a safe, clinically feasible method for locating root canals could be a new development direction for minimally invasive endodontics.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Hospital of Stomatology, Guangzhou Medical University and written informed consent was obtained from the participants.

Consent to publish

The authors agree to publication in the journal.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

Competing interests

The authors declare that they have no competing interests.

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Authors’ Contributions

YXC come up with this idea. XJ and WWD designed and manufactured the 3D printed template. XJ and LZM were participated in the analytical CT data. JQZ was participated in the clinical operation. ZQ and LBP were responsible for the literature search and wrote the paper. All authors read and approved the final manuscript.

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References

1. Ørstavik D, Pitt Ford TR. Apical periodontitis: microbial infection and host responses. In: Ørstavik D, Pitt Ford TR (eds) Essential Endodontology: prevention and treatment of apical periodontitis Oxford: Blackwell Science; 1998. P. 1– 8.
2. Schroeder KP, Walton RE, Rivera EM. Straight line access and coronal flaring: effect on canal length. J Endod 2002;28: 474–6.
3. Patel S, Rhodes J. A practical guide to endodontic access cavity preparation in molar teeth. Br Dent J 2007; 203: 133–40.
4. Pereira JR, McDonald A, Petrie A, Knowles JC. Effect of cavity design on tooth surface strain. J Prosthet Dent 2013; 110: 369–75.
5. Chen SC, Chueh LH, Hsiao CK, Wu HP, Chiang CP. First untoward events and reasons for tooth extraction after nonsurgical endodontic treatment in Taiwan. J Endod 2008; 34: 671–4.
6. Gluskin AH, Peters CI, Peters OA. Minimally invasive endodontics: challenging prevailing paradigm. Br Dent J 2014; 216: 347–53.
7. Clark D, Khademi J. Modern molar endodontic access and directed dentin conservation. Dent Clin North Am 2010; 54: 249–73.
8. Chen Y, Jia X, Qiang M, Zhang K, Chen S. Computer-Assisted Virtual Surgical Technology Versus Three-Dimensional Printing Technology in Preoperative Planning for Displaced Three and Four-Part Fractures of the Proximal End of the Humerus. J Bone Joint Surg Am 2018;100: 1960–8.
9. Shaheen E, Sun Y, Jacobs R, Politis C. Three-dimensional printed final occlusal splint for orthognathic surgery: design and validation. Int J Oral Maxillofac Surg 2017; 46: 67–71.
10. Bukhari S, Goodacre BJ, AlHelal A, Kattadiyil MT, Richardson PM. Three-dimensional printing in contemporary fixed prosthodontics: A technique article. J Prosthet Dent 2018; 119: 530–4.
11. Ciocca L, De Crescenzio F, Fantini M, Scotti R. CAD/CAM and rapid prototyped scaffold construction for bone regenerative medicine and surgical transfer of virtual planning: a pilot study. Comput Med Imaging Graph 2009, 33(1):58–62.
12. Krastl G, Zehnder MS, Connert T, Weiger R, Kühl S. Guided endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. Dent Traumatol 2016; 32: 240–6.
13. Shi X, Zhao S, Wang W, Jiang Q, Yang X. Novel navigation technique for the endodontic treatment of a molar with pulp canal calcification and apical pathology. Aust Endod J 2018; 44: 66–70.
14. Connert T, Zehnder MS, Weiger R, Kühl S, Krastl G. Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth. J Endod 2017; 43(5) 787–90.
15. Zehnder MS, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J 2016; 49: 966–72.
16. Silva Emmanuel João Nogueira Leal,Rover Gabriela,Belladonna Felipe Gonçalves et al. Impact of contracted endodontic cavities on fracture resistance of endodontically treated teeth: a systematic review of in vitro studies.[J].Clin Oral Investig, 2018, 22: 109–118.

17. Neelakantan P, Khan K, Hei Ng, G P, Yip, C Y, et al. Does the Orifice-directed Dentin Conservation Access Design Debride Pulp Chamber and Mesial Root Canal Systems of Mandibular Molars Similar to a Traditional Access Design? J Endod 2018; 44: 274–9.
18. Alovisi M, Pasqualini D, Musso E, Bobbio E, Giuliano C, Mancino D, et al. Influence of Contracted Endodontic Access on Root Canal Geometry: An In Vitro Study. J Endod 2018; 44: 614–20.
19. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971; 32: 271–5.
20. Goto Y, Nicholls JI, Phillips KM, Junge T. Fatigue resistance of endodontically treated teeth restored with three dowel-and-core systems. J Prosthet Dent 2005; 93: 45–50.
21. Krejci I, Mueller E, Lutz F. Effects of thermocycling and occlusal force on adhesive composite crowns. J Dent Res 1994; 73: 1228–32.
22. Grippo JO, Chaiyabutr Y, Kois JC. Effects of cyclic fatigue stress-biocorrosion on noncarious cervical lesions. J Esthet Restor Dent 2013; 25: 265–272.
23. Krishan R, Paqué F, Ossareh A, Dao T, Friedman S. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. J Endod 2014; 40: 1160–6.
24. Lara-Mendes STO, Barbosa CFM, Machado VC, Santa-Rosa CC. A New Approach for Minimally Invasive Access to Severely Calcified Anterior Teeth Using the Guided Endodontics Technique. J Endod 2018;44: 1578–1582.
25. Moore B, Verdelis K, Kishen A, Dao T, Friedman S. Impacts of Contracted Endodontic Cavities on Instrumentation Efficacy and Biomechanical Responses in Maxillary Molars. J Endod 2016; 42: 1779–83.
26. Özyürek T, Ülker Ö, Demiryürek EÖ, Yılmaz F. The Effects of Endodontic Access Cavity Preparation Design on the Fracture Strength of Endodontically Treated Teeth: Traditional Versus Conservative Preparation. J Endod 2018; 44: 800–5.
27. Rover G, Belladonna FG, Bortoluzzi EA De-Deus G, Silva EJNL, Teixeira CS. Influence of Access Cavity Design on Root CanalDetection, Instrumentation Efficacy, and Fracture Resistance Assessed in Maxillary Molars. J Endod 2017; 43: 1657–62.
28. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 1989; 15(11) 512–6.
29. Krishan R, Paqué F, Ossareh A, Kishen A, Dao T, Friedman S. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. J Endod 2014; 40: 1160–6.

Tables Legend

Table 1. Unmodified Canal Wall after CEC or TEC preparation and Root Canal Instrumentation in premolars assessed by Micro-CT imaging

Table 2. Mean Values ± Standard Deviations of the filling material and voids volume in premolars assessed by Micro-CT imaging

Table 3. Load at fracture (mean values ± standard deviations) for premolars with CEC or TEC assessed in the Instron Universal Testing Machine

Tables

Due to technical limitations, Tables 1 - 3 are only available for download from the Supplementary Files Section.

Figures

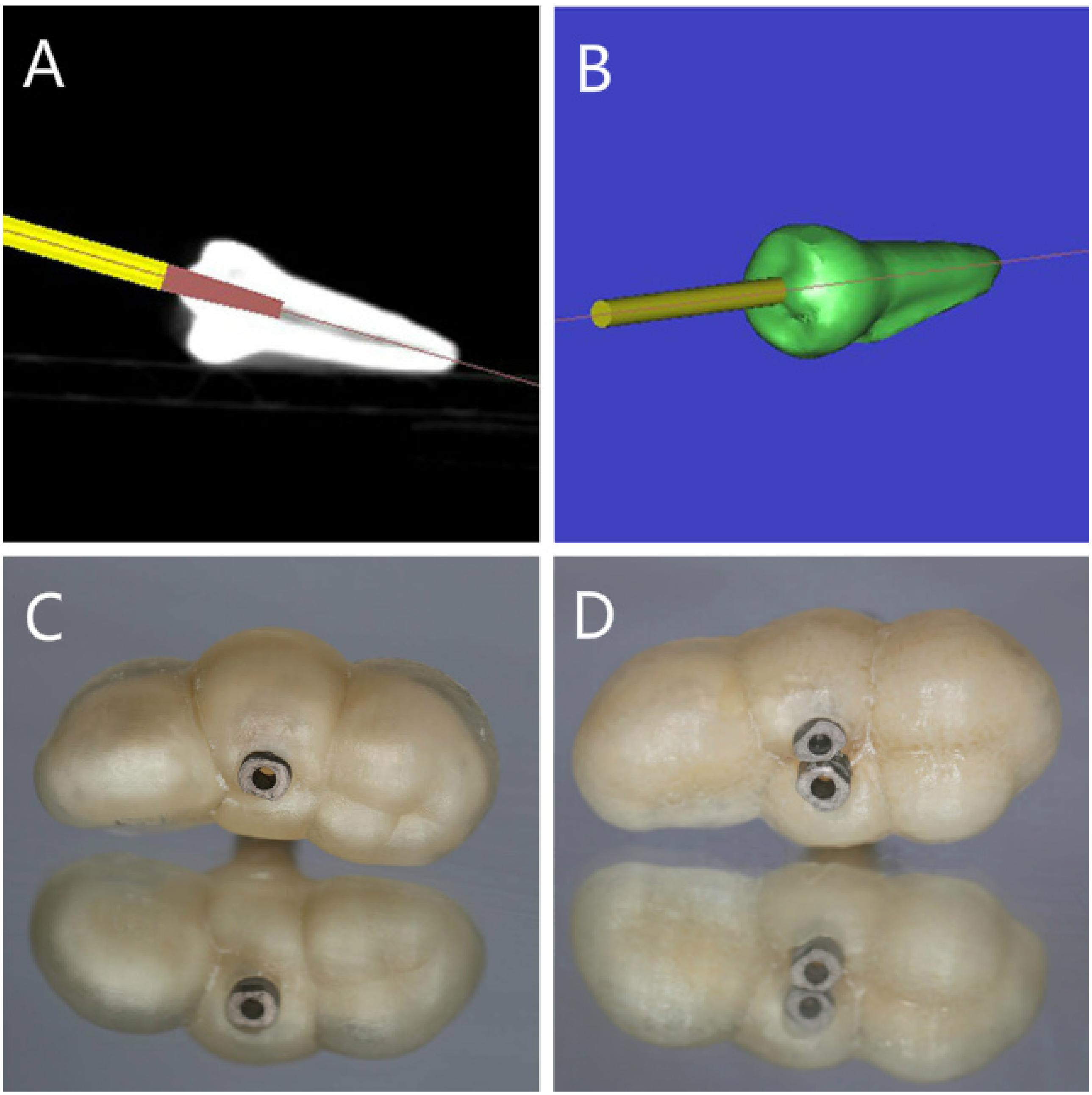

Figure 1

(A) The drill virtually superimposed on the tooth to create straight-line access to the apical third of the root canal. (B) A schematic of a drill in the tooth model. (C) A 3D-printed template positioned on the single-rooted premolar model. (D) Template positioned on the premolar with two dental roots.

Figure 2

(A) Specimens placed in the Instron Universal Testing Machine. (B) The fractured tooth and the type of fracture was recorded.

Figure 3

Preoperative (green) (A), postoperative (red), (B) and the aligned root canal (C) in 3-matic.

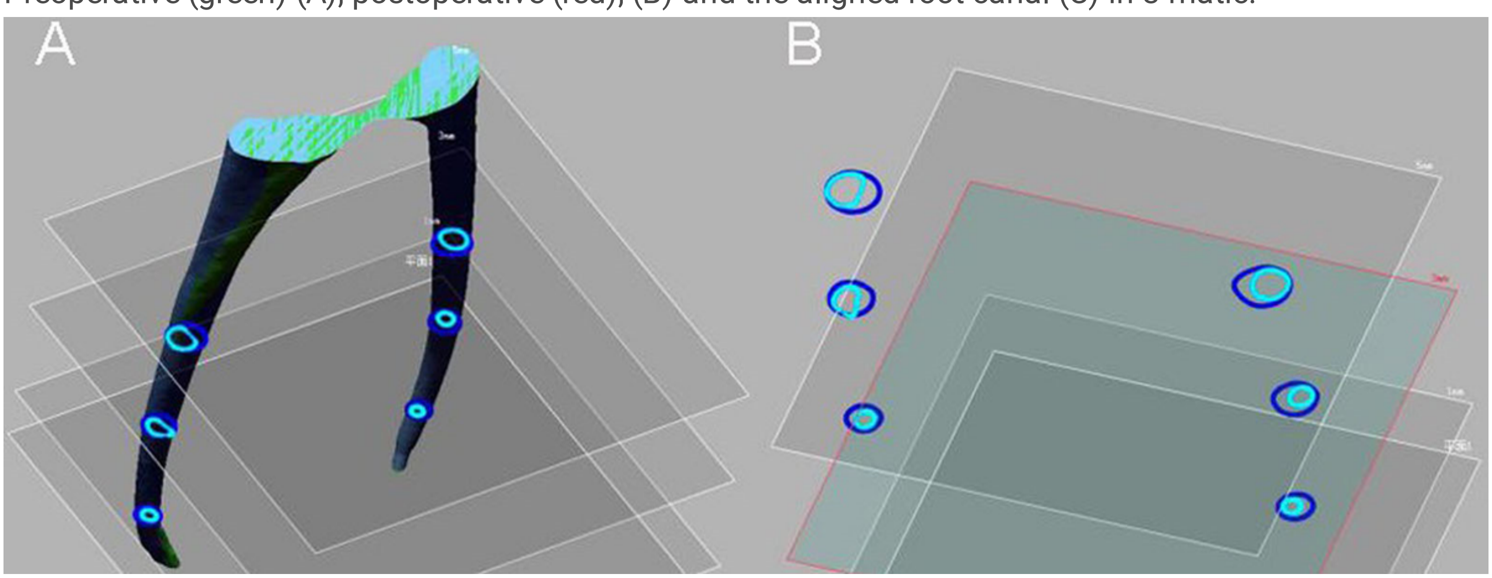

Figure 4

(A) The 1, 3, and 5 mm section from the apical. (B) The deviation of central point in Solid Work. Preoperative (aquamarine) and postoperative (mazarine).

Supplementary Files

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- Table1.pdf
- Table3.pdf
- Table2.pdf