

Impacts of conservative endodontic cavities on root canal therapy compare to traditional endodontic cavities in premolars

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Research article

Keywords: 3D-printed template, contracted endodontic cavities, instrumentation efficacy, root canal filling, fracture resistance

Posted Date: August 28th, 2019

DOI: <https://doi.org/10.21203/rs.2.13635/v1>

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Version of Record: A version of this preprint was published on September 7th, 2020. See the published version at <https://doi.org/10.1186/s12903-020-01237-w>.

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 in premolars. **Methods:** Forty extracted intact human first premolars were imaged with micro-CT and randomly assigned to CEC or TEC groups. Minimal CECs were prepared with the aid of 3D-printed guide 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, 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 compared with TECs. **Conclusion:** 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.

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]. Traditional endodontic cavities (TECs) usually emphasize the straight-line pathways into root canals to enhance instrumentation efficacy and prevent complications [2, 3], the associated loss of tooth structure could undermine the biomechanical responses of the tooth [4], especially in endodontically treated teeth [5].

Today, materials and ideas, including the development of nickel titanium instruments and the concept of minimally invasive endodontics (MIE) are rapidly changing. MIE is characterized by “a 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 long-term survival benefit [7].

Three-dimensional (3D) printing is widely used for preoperative planning, procedure rehearsal, education, custom prosthetic design and surgical guidance in medicine [8-11]. Because 3D technology could achieve precise design and positioning before operation, this technology has been applied in clinic and achieved good effects [12, 13], the accuracy and safety for 3D printed template have been proved [14,15]. The objective is to design and make 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. 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 were provided.

Methods

Selection of teeth

The present study was approved by the Ethics Committee of the Hospital of Stomatology, Guangzhou Medical University (number KY2017012). Collected extracted human first premolars from orthodontic tooth extraction in oral and maxillofacial surgery, patients were requested if they could provide their extracted premolars to be used as specimens. When they gave consent, they were asked to sign an agreement form to indicate that they were willing to provide their extracted premolars for specimens. 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 [16] on buccolingual and mesiodistal radiographs was selected. Because the selected teeth were similar dimensions, there was no statistically significant difference ($P > .05$) 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 canals. The digitally designed template was exported as a STL-file, and then was sent to a 3D printer (3D System 3510HB, 3D Systems, Morrisville, North Carolina, USA).

TEC and CEC preparation

In CEC preparation, a 3D-printed template was positioned on the tooth model, 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 directed towards their respective orifices, which kept back the truss of dentin between the cavities (Fig. 2). In the TEC group, conventional access cavities were prepared. After initial preparation with pathfile instruments (Dentsply Maillefer, Ballaigues, Switzerland), canals were prepared with .04 taper M-Two rotary instruments (VDW company, Germany) to size 35#. These instruments were used in a standard technique, The canals were irrigated with 3 ml of 5.25% sodium hypochlorite between use of each instrument, and then, each canal was irrigated with 5% NaOCl 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 to capture the instrumented canal shape (posttreatment scan). All canals were obturated with gutta-percha cones (Dentsply Sirona) 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 2mm composite resin restorative material (Gradia Direct Posterior) was placed on the canal opening. The teeth were stored in physiological saline at 37°C for one week. Each specimen was subjected to micro-CT (SkyScan 1172; Bruker micro-CT, Kontich, Belgium) before and after instrumentation and irrigation as well as after obturation.

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 [17], between 5 N-50 N at 15 HZ to simulate approximately 2 years of chewing function [18,19]. 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 [20] (Fig. 3A). The load at fracture was recorded in Newton (N), and the type of fracture was recorded (Fig. 3B).

Evaluation methodology

Canal and crown boundaries were demarcated at the buccolingual level of the cemento-enamel 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 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 posttreatment 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. 4) and we measured the sectional section of 1 mm, 3 mm, and 5 mm from the apical and the deviation of central point in Solid Work (Dassault, France) (Fig. 5). 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 were 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 ($3.85\% \pm 0.42\%$) was significantly smaller ($P < .05$) than in the TEC group ($4.94\% \pm 0.5\%$). The percentage of dentin removed has no significant differences ($P > .05$) between the TECs ($3.4\% \pm 0.13\%$) and CECs ($2.98\% \pm 0.12\%$) in the premolars with one dental root. The UCW after instrumentation for TECs ($16.43\% \pm 6.56\%$) was significantly lower ($P < .05$) than the UCW ($24.42\% \pm 9.19\%$) for CECs in single-rooted premolars. The UCW in premolars with two canal roots did not differ significantly ($P > .05$) between the TEC ($21.28\% \pm 8.91\%$) and CEC ($18.62\% \pm 5.85\%$) groups (Table 1). No significant differences were observed in the increased canal volume and surface areas in premolars between the TEC and CEC groups ($P > .05$). In the premolars with two dental roots, the increased sectional area of 1 mm, 3 mm, and 5 mm from the major apical foramen was significantly greater ($P < .05$) in the CEC group than in the TEC group. The deviation of the central point after instrumentation for TECs was significantly smaller ($P < .05$) than that for CECs. There was no significant difference ($P > .05$) 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 ($P > .05$) (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 ($P > .05$) (Table 3).

Discussion

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 [15,21]. In this study, 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.

A previous study reported that CEC seems to exhibit a better preservation of the original canal anatomy particularly at the crown level including incisors, premolars and molars with TECs [20]. 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.

The complete cleanness of 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 ($p > .05$). According to the report [22], 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 [23].

In the premolars with two dental roots, the increased sectional area was significantly bigger ($P < .05$) in the CEC group than in the TEC group. It is probably because when we design the canal orifice in the premolars with two dental roots, the drill was virtually superimposed on the root canal with inclination angle in coronal, because when we design a straight-line pathways into canals, the orifice would be in the buccal cusp, we shifted a little toward the middle to avoid the destroy of marginal ridges. Because of the inclination angle in coronal, the deviation of the central point after instrumentation for CECs was significantly bigger ($P < .05$) than that for TECs. Mario A et al also reported TECs showed more preservation of the original root canal anatomy with less apical transportation than CECs [24].

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 [22, 25, 26], this result corroborate with those above researches. The researchers have found the endodontic procedures do not weaken teeth with intact marginal ridges [27], the CEC and TEC groups were both prepared with intact marginal ridges and there were no significant differences ($P > .05$) on biomechanical responses between the premolars in the CEC and TEC groups. At the same time, the result was opposite to Krishan's research [28], which reported CEC increased fracture resistance in premolars and mandibular molars, First of all, it is probably because that we simulated clinical treatment procedure to restore the access cavities with resin before fracture resistance test; secondly, the angle of the tooth loaded at the central fossa from the tooth long axis and the spherical crosshead was different in this study; thirdly, single-rooted premolars and premolars with two dental roots were differentiated; fourthly, each sample have been tested by fatigue cycle test. All of these factors have the potential affection on the final results; In addition, the load type was comparable to that experienced in the mouth and human teeth was subjected to forces in different directions at the same time; and teeth have irregular shapes; the experimental data acquired were just in one direction and the results were for reference.

Conclusion

Within the limitations of this study, the current results did not show obvious benefits associated with CEC group compared with 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 were encouraged to carry out on this topic.

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.

Funding

This work was supported by the International Cooperation from the Science and Technology Planning Project (No. 2017A050501054), Medical Research Foundation of Guangdong province (No. A2017583), National Key R&D Program of China (No. 2018YFB116903), The project of 2018 annual Guangdong Higher Education Reform Project (No.2018-486).

The clinical materials and software equipment in this experiment come from the support of the International Cooperation from the Science and Technology Planning Project. The cost of Three-dimensional printing was supported by Medical Research Foundation of Guangdong province. The expense for the technical training was supported by the National Key R&D Program of China. The cyclic fatigue and the fracture strength test were supported of the project of 2018 annual Guangdong Higher Education Reform Project.

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.

Acknowledgements

Not applicable.

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Tables

Table 1. Unmodified Canal Wall after Conservative (CEC) or Traditional (TEC) Endodontic Cavities preparation and Root Canal Instrumentation in premolars assessed by Micro-CT imaging

UCW (% of total canal wall surface)			
Tooth type (n=10)	CEC	TEC	P value
single-rooted premolars	24.42±9.19%	16.43±6.56%	0.038
Two dental root premolars	18.62±5.85%	21.28±8.91%	0.441

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

Groups	Region	Filling material (%)	Voids (%)
TEC (single-rooted premolars)	All	95.35±2.94	4.65±2.94
	Cervical	94.52±3.69	5.48±3.69
	Middle	96.28±2.72	3.72±2.72
	Apical	96.53±3.72	3.47±3.72
CEC (single-rooted premolars)	All	96.78±1.81	3.23±1.81
	Cervical	96.83±1.76	3.17±1.76
	Middle	97.36±2.73	2.64±2.74
	Apical	98.29±1.51	1.71±1.51
TEC (two dental roots premolars)	All	91.59±3.48	8.41±3.48
	Cervical	89.82±4.1	10.18±4.1
	Middle	95.34±3.27	4.66±3.27
	Apical	95.07±5.13	4.93±5.13
CEC (two dental roots premolars)	All	91.07±6.38	8.93±6.38
	Cervical	88.45±9.06	11.55±9.06
	Middle	93.75±5.55	6.25±5.55
	Apical	96.87±3.49	3.13±3.49

CEC, contracted endodontic cavity; TEC, traditional endodontic cavity.

No statistically significant difference was observed between groups throughout the canal in each region ($p > .05$)

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

Tooth type (n=10)	Load at fracture (N)		P value
	CEC	TEC	
single-rooted premolars	926.90 \pm 194.97	888.57 \pm 165.73	0.64
two dental root premolars	665.09 \pm 168.74	630.95 \pm 159.81	0.88

Figures

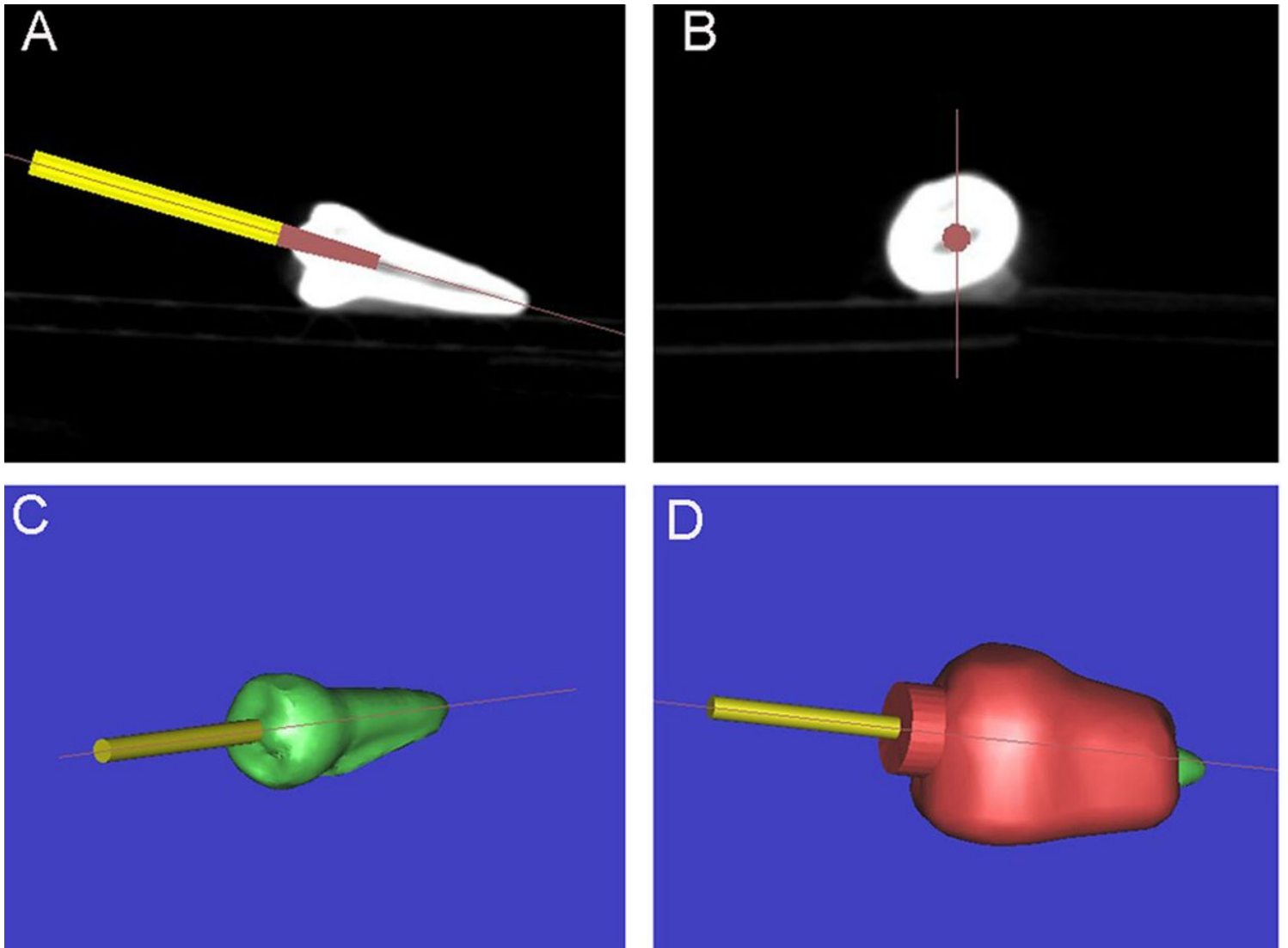


Figure 1

(A) The drill virtually superimposed on the tooth to create straight line access to the apical third of the root canal. (B) The drill in the canal on the transversal surface. (C) A schematic of a drill in the tooth model. (D) A virtual template automatic generated in the Simplant.

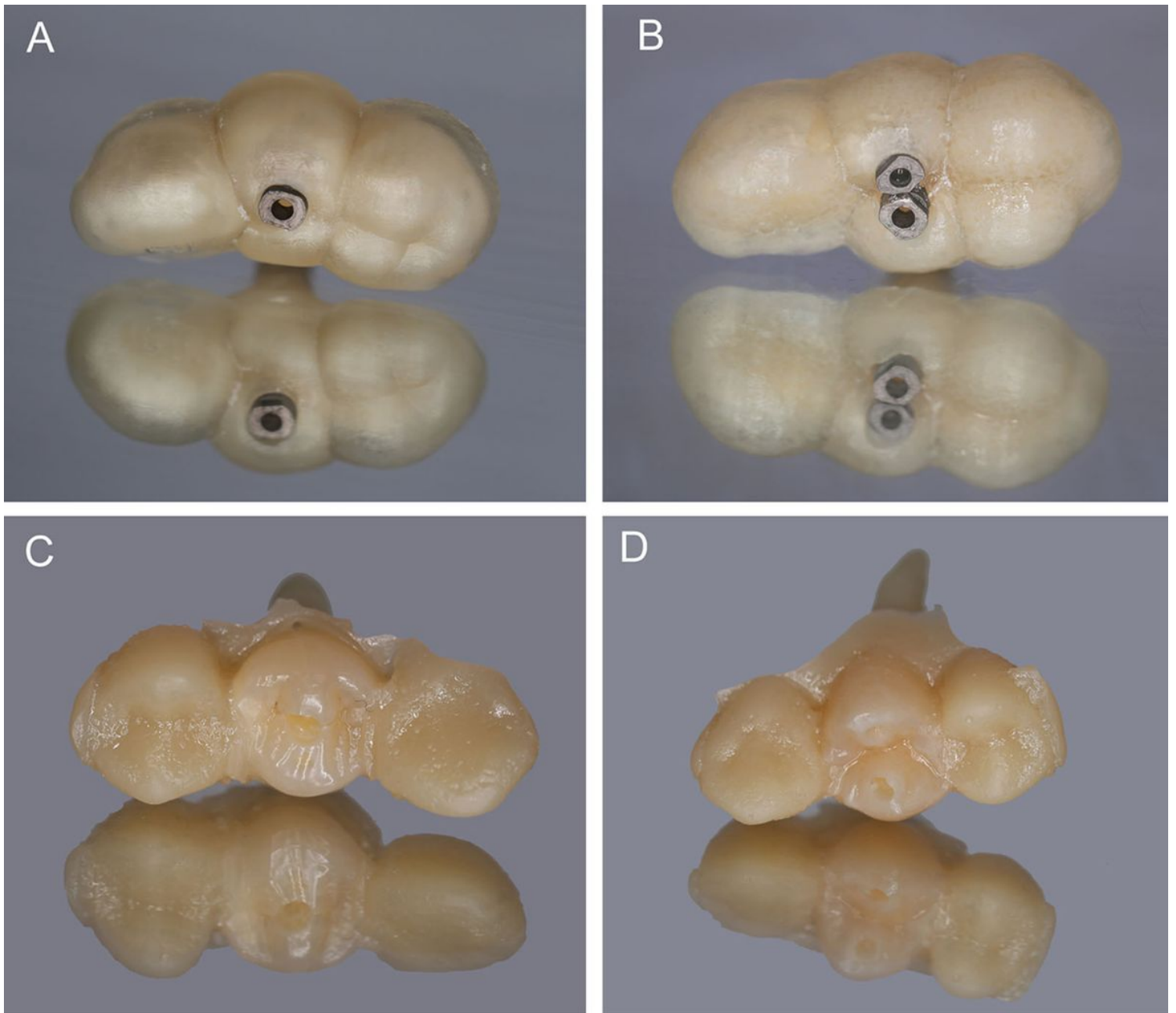


Figure 2

(A) A 3D-printed template positioned on the single-rooted premolar model. (B) Template positioned on the premolar with two dental roots. (C) Single-rooted premolars after CEC preparation. (D) Premolars with two dental roots after CEC preparation retaining the truss of the dentin between the cavities.

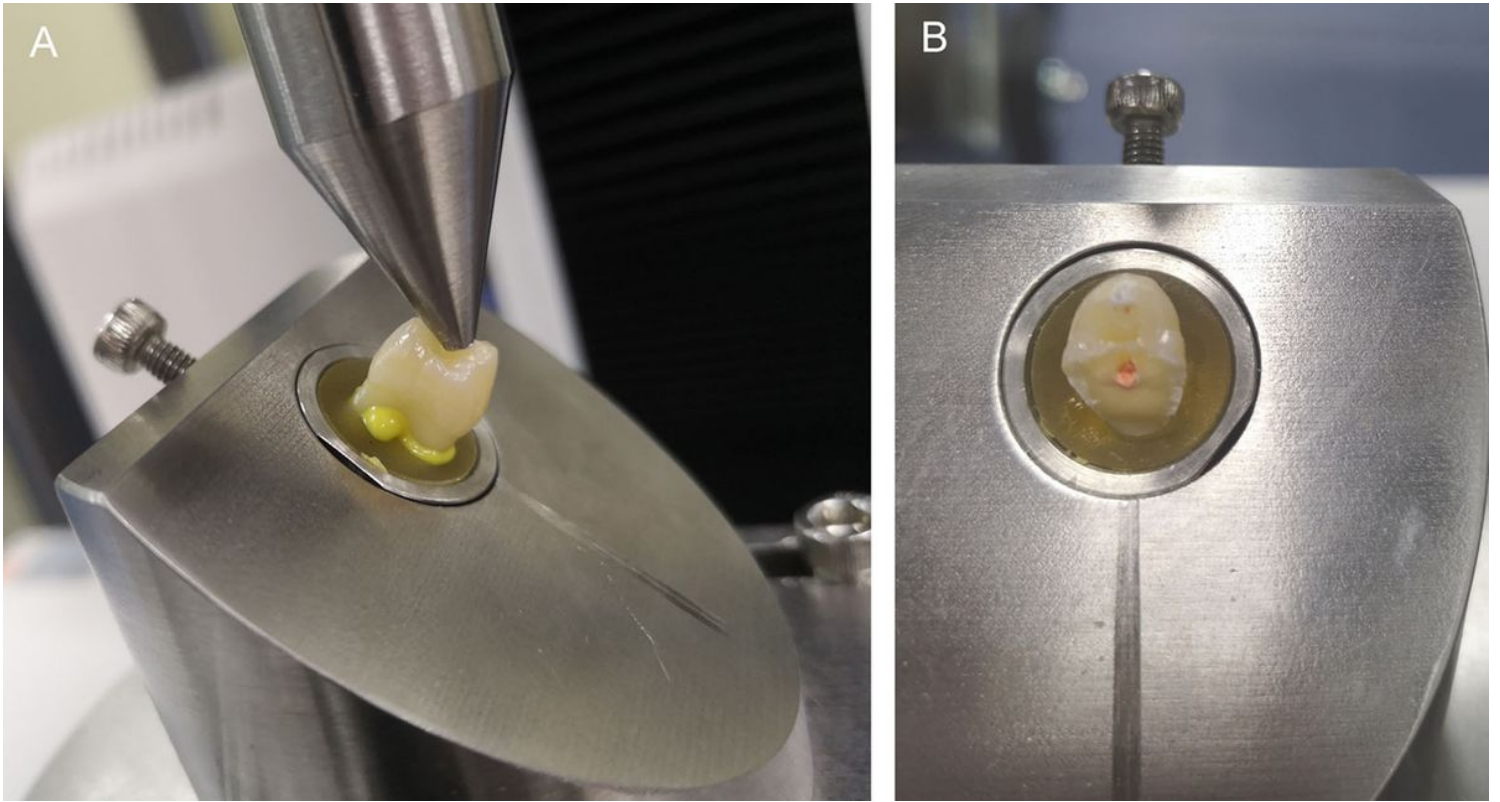


Figure 3

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

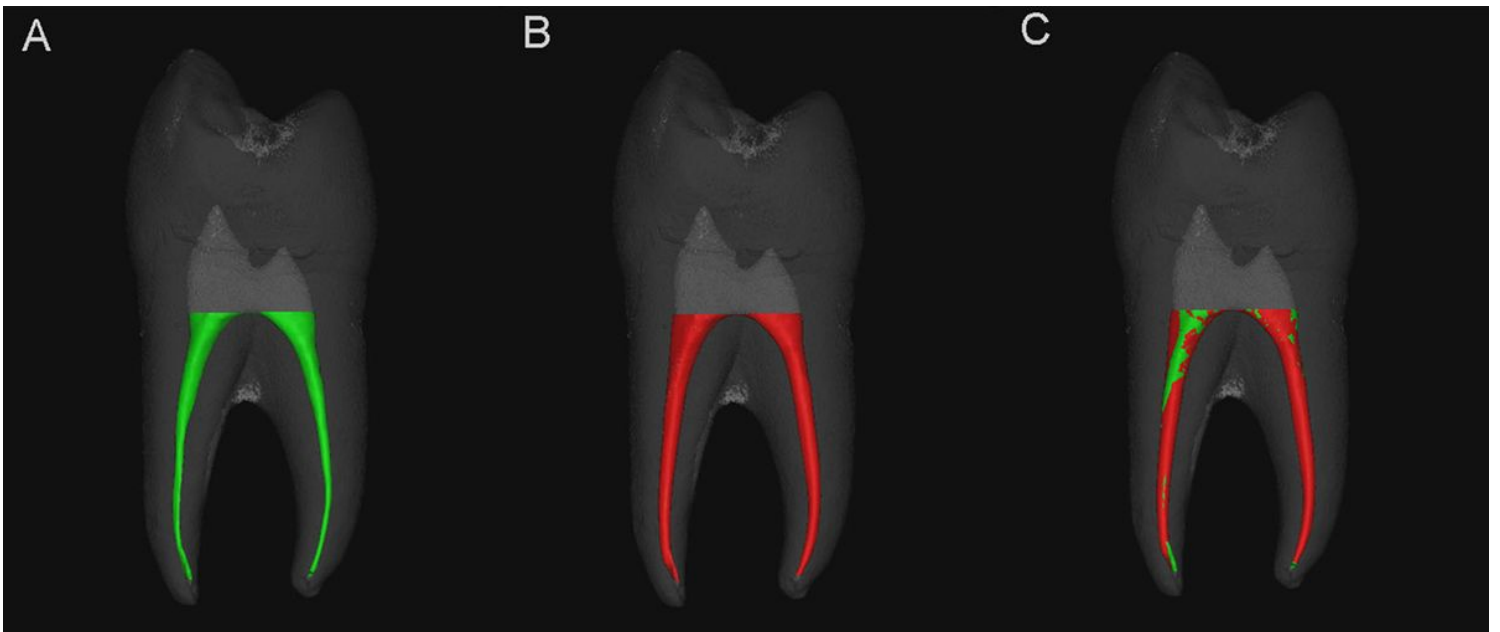


Figure 4

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

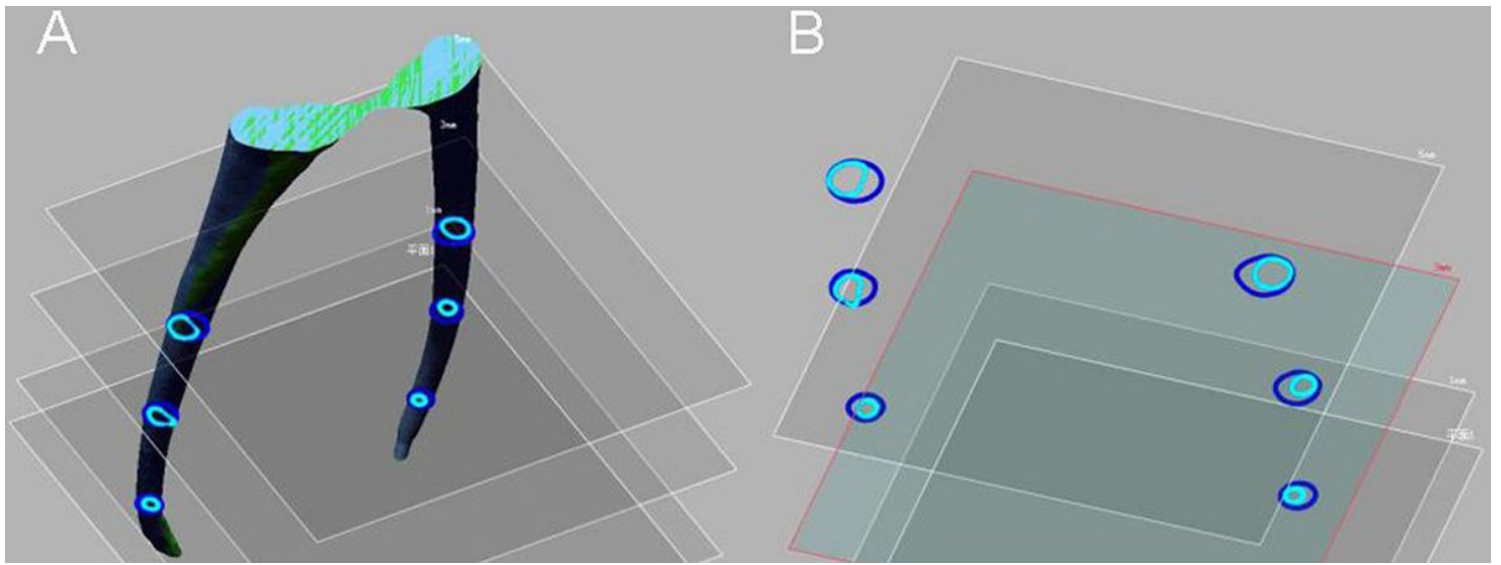


Figure 5

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