Original Research
Endodontic Therapy

Impact of access cavities on root canal preparation, restorative protocol quality, and fracture resistance of teeth

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Declaration of Interests: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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https://doi.org/10.1590/1807-3107bor-2023.vol37.0096

Submitted: May 3, 2023
Accepted for publication: June 15, 2023
Last revision: July 11, 2023

Abstract: The survival of endodontically treated teeth depends on the remaining tooth structure. The aim of this study was to evaluate the impact of different access cavities on root canal preparation, restorative protocol, and fracture resistance of endodontically treated teeth. Fifty-six mandibular molars were divided into control (n=8) and experimental (n=16) groups according to access cavity: Traditional, Conservative, and Truss; and redistributed (n=8) according to instrumentation protocols: Reciproc Blue and R-motion. After, teeth were scanned in micro-CT and then filled and redistributed according to composite resin restoration (n=8): Filtek One BulkFill and Filtek Z350. A new micro-CT scan was performed to analyze the restorative material. Then, samples were submitted to fracture resistance testing and the failure pattern was determined. Data were analyzed using paired T-test, ANOVA, Tukey, and chi-square tests (α=0.05). In Truss, R-Motion promoted less transportation in different thirds of root canals. Higher percentages of voids (5.05%) and filling material (11.7%) were observed in Truss. Fracture resistance values were higher for the control group, followed by Truss, Conservative, and Traditional. The predominant failure pattern was type-II. In Truss, reciprocating instruments with smaller taper showed less canal transportation. Also, Truss provided higher values of fracture resistance, although it presented a higher percentage of voids and remaining filling material. Thus, in Truss, reciprocating files with smaller taper showed less canal transportation, and these cavities provided higher values of fracture resistance, although it presented a higher percentage of voids and remaining filling material.

Keywords: Endodontics; Root Canal Preparation; Dental Restoration.

Introduction

The literature shows controversial results regarding the impact of endodontic access cavities on fracture resistance of endodontically treated teeth.[1,2] Some studies demonstrate that traditional endodontic access results in lower fracture resistance compared to conservative access, which preserves the pericervical dentin and part of the pulp chamber ceiling,[3-5] and the Truss access,[6,7] which leaves the central fossa and the lingual and mesio-buccal groove intact, separated by an enamel/dentin bridge in the buccal-lingual direction. On the other hand, other studies found no differences in fracture resistance of teeth endodontically treated through different endodontic accesses cavities.[2,8-11] These differences can be attributed to non-standardization of the methods used to evaluate fracture resistance, different sets of teeth, and different restorative protocol.[1] Therefore, it is necessary to discuss the technique beyond the evaluation of the restorative material used, since the restorative protocol has a direct impact on treatment prognosis.[12]

The first choice of restorative protocols for the restoration of endodontically treated teeth is the use of composite resins, which have similar mechanical properties to dentin and can restore up to 72% of the fracture resistance.[8] However, it is important to note that composite resins have high polymerization shrinkage, which can result in the formation of gaps between the tooth interface and the restorative material.[13] To mitigate this situation, bulk fill composite resin have been developed in regular and flowable forms that exhibit less polymerization contraction and have better performance than incremental composites regarding adaptability and less gap formation in the pulp wall.[14,15]

Regarding root canal preparation, the technological improvement and development of NiTi-treated alloy systems in different designs and kinematics produced a new generation of instruments with greater flexibility and resistance to cyclic fatigue. This allows creating accesses with less coronal wear. On the other hand, the use of mechanized instruments in conservative, ultraconservative, and Truss access cavities, especially those with greater taper in reciprocal kinematics, has been associated with greater apical transport and higher percentage of unprepared walls compared to their use in traditional cavities.[3,4] Recently, the R-Motion instrumentation system (FKG, Switzerland) was developed, consisting of instruments made of heat-treated NiTi alloy with a higher percentage of martensitic phase. These instruments are available in two different tapers, 0.4 and 0.6, which are smaller compared to other single instrument systems in reciprocal kinematics with larger tapers. In addition, they have a rounded triangular cross-section with cutting edges and active tip, which favors cutting and penetration efficiency with less stress on the dentin.[16]

Thus, the aim of the present study was to evaluate the impact of different access cavities on root canal preparation using reciprocating instruments with low taper on the restorative protocol and fracture resistance of endodontically treated teeth restored with different low-viscosity resins. The null hypothesis was that the different access cavities do not impact on root canal preparation, restorative protocol, and fracture resistance of endodontically treated teeth.

Methodology

Sample selection

The G*Power version 3.1.9.7 software (Düsseldorf, Germany) was used to determine the sample size by means of F-tests and Anova for fixed, special, main, and interaction effects. Type I error of $\alpha = 0.05$, statistical power $\beta=0.8$, numerator dF = 3, number of groups = 6 or 7 were used as fixed parameters. From previous studies, the effect size was determined to be 0.5 and 0.52 for percentage of change in volume and surface area,[17] 0.50 for percentage of unprepared root canal walls,[3,8] 0.55 for voids in the coronal restoration[1] and 0.60 for fracture resistance.[3,4,8,18] From these parameters, the estimated minimum sample size was 8 specimens per group for percentage of volume and surface area change, 7.5 for percentage of unprepared root canal walls, 6.83 for voids, and 5 for fracture resistance. Thus, the sample size was set at 8 specimens for each group, and a total of 56 samples.

After approval of this study by the local ethics committee (No 42341321.0.0000.5419), healthy human mandibular molars recently extracted due to periodontal diseases, without caries, with complete root formation, and without macroscopically visible fracture were preselected. The teeth were scanned using a 1174 v.2 SkyScan microcomputed tomograph, operated at 50 kV, 276 mA, isotropic resolution of 23.5 µm, 360° rotation around the vertical axis, 1.8° rotation step, total of 2 frames, and a 0.5-mm thick aluminum filter. In order to ensure proper alignment of the images taken at different stages of the study, the teeth were positioned with their buccal surfaces perpendicular to the radiation source. The two-dimensional images were reconstructed in NRecon v.1.6.6.0 software (Bruker microCT, Kontich, Belgium) and analyzed in CTAn v.1.14.4.1+ software (Bruker microCT, Kontich, Belgium) to calculate crown and root length and volume, and determine root canal volume and surface area. From these data, 56 mandibular molars with 2 mesial canals (type IV) and one distal canal (type I)[19] were selected and grouped according to anatomical aspects, randomized and divided into 1 control (n = 8) and 2 experimental (n = 16) groups according to the type of access cavity: Traditional (TAC), Conservative (CAC), and Truss. Then, samples were randomized again and divided according to root canal preparation protocol (n = 8): Reciproc Blue (RB) and R-motion (RM). The homogeneity of the morphological aspects between groups was checked using one-way ANOVA test ($p > 0.05$) and two-way ANOVA test ($p > 0.05$), respectively. The randomizations were performed using SPSS software (SPSS, Inc., Chicago, USA).

All experimental procedures were performed by a single expert using a DM Plus IB surgical microscope (Opto Eletrônica, São Carlos, Brazil) with 2× to 12× magnification. In the control group, the teeth remained intact and were used only for fracture resistance and failure pattern evaluation.

Endodontic access cavity

The endodontic access cavities were prepared following the classification proposed previously.[20] For the preparation of the traditional access (TAC), a 1014HL spherical diamond bur (KG Sorensen, São Paulo, Brazil) was used at high rotation, positioned in the center of the main groove parallel to the long axis of the tooth with a slight inclination towards the distal canal until reaching the pulp chamber, followed by "in-out" movements until the entire pulp chamber roof was removed. Next, an Endo Z bur (Dentsply Sirona, Ballaigues, Switzerland) was used for smoothing the cavity walls and slightly diverge them toward the occlusal surface, resulting in a trapezoidal shape (Figure 1A and 1D). For the conservative endodontic access cavities (CAC), the same steps as for traditional cavities were followed until the pulp chamber was reached, but "in to out" movements in the pulp chamber were performed until interference-free access to the root canal openings was achieved. Then, an E7D ultrasonic insert with diamond tip (Helse Ultrasonic, Santa Rosa do Viterbo, SP, Brazil) was used to smooth the cavity walls, which converged towards the occlusal surface to preserve the cusps (Figure 1B and 1E). For the Truss access cavity, a 1013HL spherical diamond bur (KG Sorensen) was used for the access, and an ultrasonic insert with E7D and E4D diamond tips (Helse) was used for the refinement of the cavity. After analyzing the volume of the pulp chambers on micro-CT, a standard design of the access was performed[20] (Figure 1C and 1F).

Root canal preparation

The working length (WL) was established at 1 mm below the apical foramen. The root canal preparation was performed with the Reciproc Blue (RB) or R-motion (RM) reciprocating systems, following the manufacturer's recommendations, powered with a Sirona 6:1 counter angle reducer (SN 25185; VDW GmbH, Munich, Germany) coupled to the SMR 114058 motor (VDW GmbH), which was connected to the VDW Silver electric motor (VDW GmbH) with reciprocating motion selection. To standardize the irrigation volume during preparation, root canals were irrigated with 10 mL of 2.5% NaOCl. For the RB group, the mesial canals were prepared with the R25 file (25.08) and the distal canals with the R50 file (50.05). For the RM group, the glide path was initially performed with 15.03 RM file and then the mesial canals were prepared with the 30.04 RM and the distal canals with the 50.04 RM files. The final irrigation was performed with 2 mL of 17% etylenediaminetetraacetic acid (EDTA) for 5 minutes, followed by 10 mL of distilled water. The specimens were re-scanned in micro-CT for reconstruction and data analysis after root canal preparation following the same parameters as before.

3D evaluation of root canal preparation

Post-instrumentation images were aligned with the images obtained in the initial microtomographic

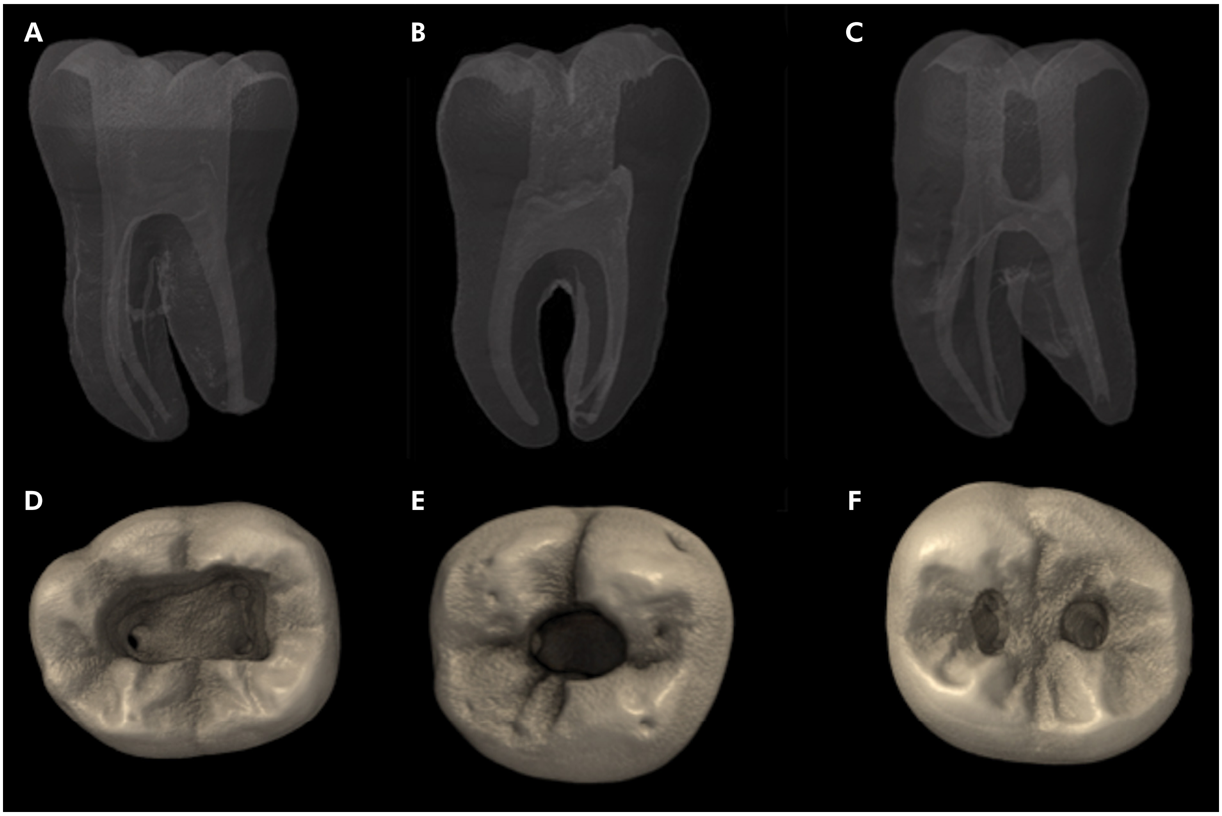

Figure 1. Schematic representation of access cavities in micro-CT images. Sagittal reconstruction in first line and axial reconstruction in second line. (A) and (D) show Traditional access cavity; (B) and (E) show Conservative access cavity; (C) and (F) show Truss access cavity.

examination (pre-instrumentation) in the DataViewer v.1.5.0 software. Using the 3D Analysis tool of the CTAn software, data on crown and root volume were obtained, as well as the three-dimensional morphometric parameters of the root canal volume, surface area, calculation of transportation in the cervical, middle and apical thirds, and the percentage of prepared and unprepared walls (15,17). In addition, the percentage of coronal structure removal (% removal) after performing the endodontic accesses was determined by the formula %removal = (Initial Volume - Remaining Volume)*100/(Initial Volume), where "Remaining Volume" corresponds to the remaining coronal volume and "Initial Volume" corresponds to the initial coronal volume.

Root canal filling and restorative procedures

The root canal filling was performed using the single cone technique with AH Plus sealer and gutta-percha cones Reciproc Blue R25 and R50 (VDW GmbH) in the mesial and distal root canals, respectively, for the Reciproc Blue group, and cones 30.04 and 50.04 (FKG Dentaire, La Chaux-de-Fonds, Switzerland) for the RM group. The cleaning of the pulp chamber was performed with 70 percent isopropyl alcohol and Soffitsonic ultrasonic insert (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil). The coronal volumes obtained after root canal preparation were used for further randomization (two-way ANOVA, p>0.05) and distribution into two experimental subgroups (n = 8), according to restorative protocol, for each access cavity group.

For the restorative procedures, selective acid etching was performed on enamel with 37% phosphoric acid (Ultradent Products, Inc., South Jordan, USA) for 30 seconds. The cavities were washed for 30 seconds with water jets and lightly dried with air jets and absorbent paper. The SingleBond Universal adhesive system (3M ESPE, St Paul, USA) was then applied to enamel and dentin for 20 seconds, followed by solvent evaporation with light air jets for 10 seconds, and photoactivation with a LED unit in standard mode at 1000 mW/cm^2 (VALO, Ultradent Products) for 20 seconds.

For the restorative protocol with Filtek Z350 resins (FZ350) (3M), two layers of 2 mm each of Filtek Z350 flow resin (FZ350-F) were applied and the rest of the cavity was filled with 2 mm oblique increments with regular Filtek Z350 (FZ350), each increment being light-cured for 10 seconds. For the restorative protocol with Filtek One Bulk Fill resins (FOBF) (3M), a 4 mm layer of Filtek One Bulk Fill flow resin (FOBF-F) was applied, followed by the addition of a single increment of regular Filtek One Bulk Fill (FOBF), and each layer was light-cured for 20 seconds.

A standard mode LED-curing unit (VALO, Ultradent Products Inc) with a power of 1000mW/cm^2 was used, with the tip of the light placed on the tooth cusps. Analysis and measurement of the irradiance values (1,000 mW/cm^2), emission spectrum, and total energy delivered were performed with a radiometer (PM10-19C; Coherent, Ely, UK) for each sample. After 24 hours of storage at 37°C in 100% relative humidity, the restorations were finished and polished with diamond tips (KG Sorensen, Barueri, Brazil) and abrasive rubber tips (KG Sorensen, Barueri, Brazil).

Determining the remaining filling material and voids in the restoration

Due to the different densities of the restorative and filling materials, after the root canal filling and restoration protocols, the specimens were re-scanned in Sky Scan microCT (1176 model, Bruker mi-croCT) operated with 90 kV, 276 mA, with a resolution of 23.5 µm and 360° on the vertical axis with rotation steps of 0.7° using a 0.5 mm aluminum filter. The images were reconstructed (NRecon software) and analyzed using CTAn software to determine the volume of restorative material (mm^3) ($Vol_{restorativematerial}$), volume of empty spaces in the restoration (mm^3) (Vol_{spaces}), and volume of remaining filling material (RFM) across the entire length of the pulp chamber, with the floor of the cavity as the end reference.

Fracture resistance test

The teeth were embedded in polystyrene resin with the periodontal ligament simulated with polyether-based molding material (Impregum F, 3M ESPE, St. Paul, USA)[1] and subjected to compressive loading at a speed of 0.5 mm/min in a universal testing machine EMIC 23-5S (Instron Corporation, Canton, MA, USA) with a 5000 N load cell. The load was applied to the central fossa using a stainless-steel rod with a tip diameter of 8 mm at an angle of 30° to the long axis of the tooth. The fracture type was analyzed under a stereomicroscope (Leica M165C, Leica Microsystems GmbH, Wetzlar, Germany) at 2X magnification. The types of fracture were classified into: Type I (crown fractures involving the occlusal or middle thirds of the crown), Type II (crown fracture involving the cervical third of the crown), Type III (root fracture involving the cervical third of the root), and Type IV (root fracture involving the middle or apical third of the root).[1]

Statistical analyses

The tests were performed in SPSS software, version 25 (IBM, SPSS, Armonk, USA), with a significance level of 95% ($p < 0.05$). Data were subjected to normality (Shapiro-Wilk) and homogeneity of variance (Levene) tests. The impact of the endodontic cavity on the root canal preparation regarding volume, surface area, and percentage of prepared walls was evaluated using a three-way analysis of variance and Tukey post-test. Root canal transportation was evaluated using split-plot ANOVA for the influence of endodontic access cavities, instrumentation protocols, and root canal thirds. Data related to the restorative protocol and fracture resistance test were subjected to three-way ANOVA and Tukey post-test for multiple comparisons between groups. The failure pattern was analyzed by the chi-square test. All tests were performed in SPSS software, version 25 (IBM, SPSS, Armonk, USA), with 95% significance level ($p < 0.05$).

Results

3D analysis of changes in root canal

Regarding surface area and volume, the results showed no statistically significant difference between types of cavity and instrumentation systems, in any of the evaluated canals (p > 0.05) (Table 1). Regarding the percentage of prepared and unprepared walls, the type of endodontic access cavity did not result in differences between the different instrumentation systems, in any of the evaluated canals (p > 0.05) (Table 1).

For root canal transportation, no statistically significant differences were observed in TAC and CAC between the instrumentation protocols (p > 0.05) (Table 2). In Truss, the RM promoted the lowest transport values for the mesio-buccal canal in the

Table 1. Mean and Standard Deviation of Morphometric Tridimensional Data of surface area (mm^2), volume (mm^3), and percentage of prepared walls of root canals of mandibular molars according to the root canal preparation protocols.

Root canal	TAC		CAC		TRUSS	
	RB	RM	RB	RM	RB	RM
Volume (Δ)						
MB	2.08 ± 0.75	1.92 ± 0.86	2.08 ± 0.75	1.75 ± 0.79	1.82 ± 1.02	1.71 ± 1.21
ML	2.12 ± 0.98	1.85 ± 0.65	2.11 ± 0.81	1.81 ± 0.72	1.91 ± 0.92	1.69 ± 1.12
D	2.92 ± 1.97	1.48 ± 1.55	2.45 ± 0.97	1.30 ± 1.60	2.02 ± 1.19	1.78 ± 1.27
Surface area (Δ)						
MB	3. 24 ± 1.25	2.59 ± 0.94	3.21 ± 1.26	2.39 ± 0.87	3.11 ± 1.29	2.51 ± 1.04
ML	3.25 ± 1.32	2.68 ± 0.86	3.18 ± 1.29	2.45 ± 0.91	3.04 ± 1.21	2.76 ± 1.09
D	6.47 ± 2.35	4.91 ± 1.74	6.47 ± 2.63	4.81 ± 1.93	6.85 ± 2.49	5.62 ± 2.08
Prepared walls (%)						
MB	75,96 ± 4,13	78,43 ± 4,41	75,82 ± 4,63	75,62 ± 3,61	78,42 ± 4,25	76,47 ± 3,84
ML	76,26 ± 3,96	76,52 ± 4,69	77,55 ± 5,10	75,95 ± 4,25	77, 15± 5,10	75,55 ± 4,29
D	76.50 ± 6.30	75.63 ± 7.28	78.43 ± 4.34	77.67 ± 3.28	76.25 ± 5.51	73.88 ± 3.53

Δ, mean increase (±standard deviation) of the analyzed parameter. MB: mesio-buccal, ML: mesio-lingual, D: distal. TAC: Traditional Access Cavities, CAC: Conservative Access Cavities, TRUSS: Truss Access Cavities. RB: Reciproc Blue, RM: R-Motion.

Table 2. Mean and standard deviation of root canal transportation by thirds for endodontic access cavities and instrumentation protocols.

Root canal	TAC		CAC		TRUSS	
	RB	RM	RB	RM	RB	RM
Cervical						
MB	0.180 ± 0.06Aa	0.163 ± 0.04Aa	0.111 ± 0.06Aa	0.095 ± 0.04Aa	0.300 ± 0.05Aa	0.265 ± 0.08Aa
ML	0.114 ± 0.16Aa	0.131 ± 0.15Aa	0.072 ± 0.04ABa	0.087 ± 0.04Aa	0.267 ± 0.16Ab	0.059 ± 0.04BCa
D	0.133 ± 0.03Aa	0.124 ± 0.03Aa	0.063 ± 0.05ABa	0.042 ± 0.04Aa	0.084 ± 0.03Ca	0.066 ± 0.05BCa
Middle						
MB	0.179 ± 0.05Aa	0.191 ± 0.06Aa	0.043 ± 0.01Ba	0.048 ± 0.02Aa	0.225 ± 0.06Ab	0.105 ± 0.02Ba
ML	0.088 ± 0.04ABa	0.073 ± 0.05ABa	0.102 ± 0.07ABa	0.066 ± 0.05Aa	0.248 ± 0.03Ab	0.187 ± 0.04ABa
D	0.048 ± 0.02Ba	0.060 ± 0.03Ba	0.031 ± 0.01Ba	0.025 ± 0.04Aa	0.269 ± 0.07Ab	0.057 ± 0.01BCa
Apical						
MB	0.125 ± 0.10Aa	0.188 ± 0.11Aa	0.082 ± 0.05ABa	0.072 ± 0.02Aa	0.167 ± 0.02Bb	0.044 ± 0.02Ca
ML	0.038 ± 0.01Ba	0.037 ± 0.02Ba	0.055 ± 0.04Ba	0.078 ± 0.05Aa	0.130 ± 0.04Bb	0.051 ± 0.02Ca
D	0.040 ±0.03Ba	0.044 ± 0.04Ba	0.097 ± 0.04ABa	0.107 ± 0.07Aa	0.152 ± 0.01Bb	0.097 ± 0.01Ba

Different uppercase letters indicate statistical differences in columns and different lowercase letters indicate statistical differences in lines ($p<0.05$). MB: mesio-buccal, ML: mesio-lingual; D: distal. TAC: Traditional Access Cavities, CAC: Conservative Access Cavities, TRUSS: Truss Access Cavities. RB: Reciproc Blue, RM: R-Motion.

middle and apical thirds ($p < 0.05$), for the mesio-lingual canal in the cervical, middle, and apical thirds ($p < 0.05$), and for the distal canal in the middle and apical thirds ($p < 0.05$), compared to the RB (Table 2).

The Truss access resulted in the lowest mean percentages of tooth structure removal (5.51 ± 0.74%), showing a statistically significant difference compared to the conservative access cavities (CAC) (14.66 ± 0.70%) and traditional access cavities (TAC) (19.95 ± 0.84%) ($p < 0.05$).

Analysis of root canal filling and restorative procedures

The Truss access resulted in a higher percentage of remaining filling material (Table 3), followed by the CAC and the TAC ($p < 0.05$).

The qualitative analysis of the three-dimensional models showed the presence of voids in the junction areas between the composite resin increments of the FZ350 and FOBF groups, and at the tooth/restoration interface for the TAC and CAC. For the Truss, voids were observed mainly under the pulp

Table 3. Mean (± standard deviation) percentage of voids in restorative material and remaining filling material for endodontic access cavities and restorative materials on tooth/restorative material set.

Variables	TAC	CAC	TRUSS
% voids			
Filtek Z350	0.27 ± 0.77A	0.44 ± 0.63A	5.05 ± 2.49B
Filtek One Bulk Fill	0.24 ± 0.19A	0.38 ± 0.59A	4.80 ± 2.42B
% remaining filling material	0.19 ± 0.07A	0.47 ± 0.40A	11.7 ± 5.70B

Different letters indicate statistical differences between access cavities ($p < 0.05$).

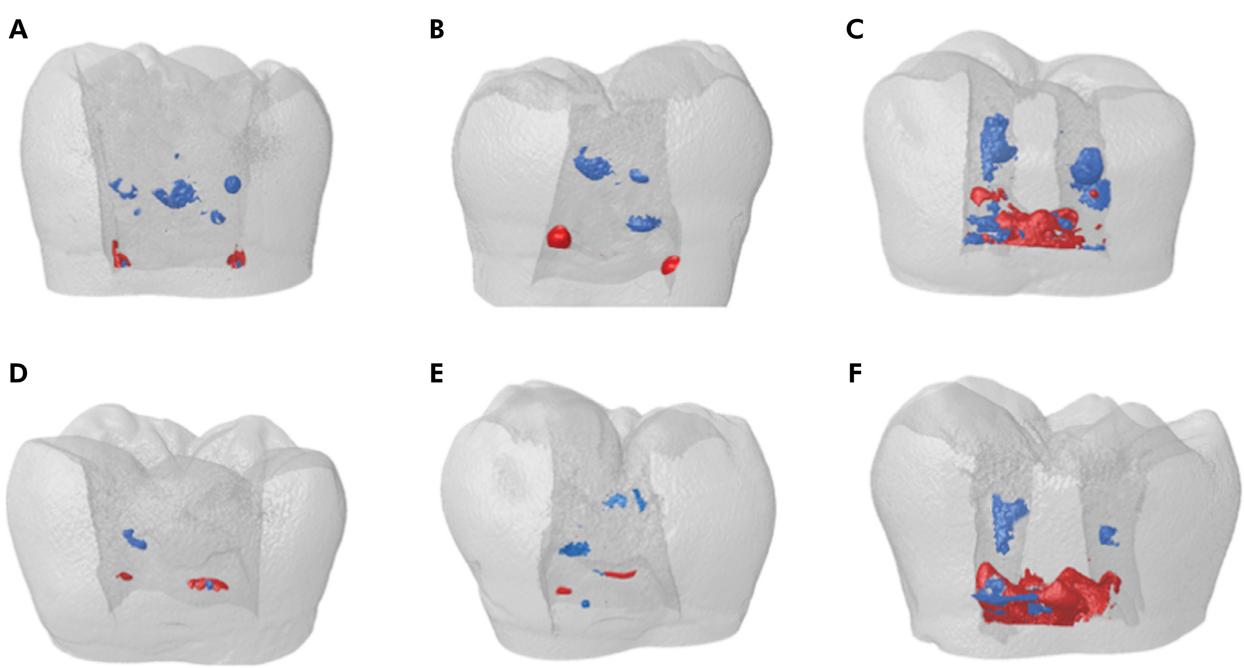

Figure 2. Micro-CT images of restorative material (gray), empty spaces (blue), and residual filling material (red) in Traditional (A and D), Conservative (B and E), and Truss (C and F) access cavities restored with Filtek One Bulk Fill (first line) and Filtek Z350 (second line).

Table 4. Mean (±standard deviation) fracture resistance in Newtons (N) and failure pattern for endodontic access cavities and restorative material.

Groups	Fracture resistance (N)	Failure pattern			
		I	II	III	IV
Control (Healthy tooth)	2280.80 ± 181.5a	3	4	1	0
TAC + FZ350	1047.47 ± 145.5b	0	5	2	1
TAC + FOBF	1113.99 ± 146.7b	0	5	2	1
CAC + FZ350	1332.07 ± 142.9c	1	4	2	1
CAC + FOBF	1470.14 ± 145.3c	2	3	3	0
TRUSS + FZ350	1699.23 ± 170.6d	1	2	4	1
TRUSS + FOBF	1934.63 ± 151.5d	1	3	2	2

Different letters indicate statistical differences in lines (p<0.05). TAC: Traditional Access Cavities, CAC: Conservative Access Cavities, TRUSS: Truss Access Cavities. FZ350: Filtek Z350 flow resin combined with Filtek Z350 regular, FOBF: Filtek One Bulk Fill flow resin combined with Filtek One Bulk Fill regular.

chamber roof, on the buccal and lingual walls, and between the layers of restorative material (Figure 2).

The Truss showed a higher percentage of voids compared to the TAC and CAC ($p < 0.05$). Regarding the restorative material, there were no statistically significant differences between cavities restored with FOBF and FZ350 resin ($p > 0.05$) (Table 3).

The highest values of fracture resistance were observed for the control group (intact teeth), which was statistically different from the experimental groups ($p < 0.05$) (Table 4). Among the experimental groups, the Truss access resulted in the highest values of fracture resistance, being statistically different from the CAC and TAC ($p<0.05$), regardless of the instrumentation and restorative protocols used. The type II failure pattern was more prevalent in all evaluated groups ($p < 0.05$), regardless of the restorative protocol used (Table 4).

Discussion

With the introduction of mechanized instruments in the 80's, modifications to the shape of the endodontic access cavity were proposed to preserve coronal tissue. Initially, the guidelines recommended large cavities that allowed straight access to the root canals.[21] Technological improvement of instruments[22,23] and emergence of magnifying tools[24,25] allowed preparation of smaller cavities with less wear of the coronal tissue, aiming to decrease the risk of tooth fracture.[20,26-28] However, these changes can affect root canal preparation and restorative protocol,[1,4,6,9,10,27] besides favoring the longevity of the endodontically treated teeth. Thus, the present study analyzed the impact of different access cavities on root canal preparation, tooth/restorative material set, and fracture resistance in the same specimen to have an integrated analysis of the observed results, since the prognosis of endodontic treatment is related not only to the endodontic technique, but also to the restorative protocol.[1,11] The different access cavities led to different results regarding impact on root canal preparation, restorative protocol, and fracture resistance, which reject the null hypothesis of this study.

The Truss access provided greater transportation in the mesiobuccal canal compared to the CAC ($p < 0.05$), which, in turn, provided greater transportation compared to the TAC ($p < 0.05$), regardless of the instrument used ($p > 0.05$). However, with the use of instruments with smaller taper (RM) in the Truss access, lower transport values were observed in the middle and apical thirds for the mesiobuccal canal ($p < 0.05$), in the cervical, middle and apical thirds for the mesio-lingual canal ($p < 0.05$), and in the middle and apical thirds for the distal canal ($p<0.05$), compared to instruments with larger taper (RB). This can be attributed to the volume of the metal mass of the file, which is directly affected by the taper, the cross-section design, and the tip diameter.[29]

The R-motion and Reciproc Blue instrumentation systems presented similar values of volume, surface area, and percentage of prepared root canal walls regardless of cavity shape ($p > 0.05$). These results can be attributed to the design of the instruments, since the R-Motion files have an active part with fixed taper that is the same in D0 and D16.[16] Therefore, the R- Motion 30.04 file presents a final diameter (D16) of 0.94 mm, close to the Reciproc Blue 25.08 file, which has a fixed taper of 0.08 in the first 3 mm (D0 to D3) and final diameter (D16) of 1.05 mm,[30] justifying the similar values for volume, surface area, and prepared roof canal walls ($p > 0.05$), as also observed in a previous study.[16] The lower taper of the R-Motion file allows the instrument to work freely along the root canal up to the working length, without interference in the cervical region, even with Conservative and Truss access cavities, with similar results to the files with higher tapers. In addition, instruments with greater taper tend to present higher metal mass, as the Reciproc Blue file, which impacts the resistance to torsion and shape memory effect, since the instrument tends to regain its original shape as a function of temperature.[31] This factor can lead to unnecessary dentin removal,[31] and these characteristics are not as pronounced in files with lower metal mass, such as the R-Motion.[16]

In the analysis of the tooth/restorative material set, the Truss cavity showed a higher percentage of remaining filling material in the cavity ($p < 0.05$) and a higher percentage of empty spaces, regardless of the restorative protocol ($p < 0.05$). This can be attributed to the small size of the Truss cavity and the difficulty of accessing the pulp chamber region under the roof with instruments and materials. Similarly, these factors influenced the execution of the restorative technique[32] during the resin insertion procedure in the ultraconservative access cavity,[1,33] regardless of the resin used, even with the use of operating microscopy, as recommended for cases of conservative and ultraconservative cavities.[25]

The evaluation of the remaining filling material, percentage of empty space, and fracture resistance were performed considering the entire tooth/restorative material set. For this restorative procedure, layers of flow composite resin and regular composite resin were used since flow composite resins have low surface hardness and low elasticity modulus. Because of these characteristics, flow resins cannot be used as a single restorative material, but must be coated with a surface layer of regular resin over this material in order to provide greater abrasion resistance during masticatory stresses.[14]

Regarding fracture resistance of endodontically treated teeth, the highest values were observed for the Truss cavity group compared to CAC and TAC ($p < 0.05$). This may be related to the lower percentage of dentin removal (5.51%), since the volume of lost coronal dentin plays a significant role in the prognosis of endodontically treated teeth,[26,34] regardless of remaining filling material and voids observed with this access type. Similar data were found in the analysis of the failure pattern, in which all groups showed a higher prevalence of favorable and restorable fractures (Type I, II and III),[35] similar to the control group ($p > 0.05$). This may be attributed to the preservation of the marginal ridges, which have a direct influence on the fracture pattern of the tooth structure, and correlate the type of fracture to the stress distribution pattern along the tooth structure [1]. It is worth noting that in all groups the access cavities were restored with composite resins associated with the adhesive system, which according to some authors promotes the internal reinforcement of the dental structure of the endodontically treated teeth by reducing cusp deflection.[1]

Therefore, according to the obtained results, the influence of the access cavity on root canal preparation and fracture resistance of mandibular molars is evident. Instruments with lower tapers effectively shape the root canal even in teeth with the Truss cavity. In addition, this access cavity, due to the maintenance of the enamel/dentin bridge in the labial-lingual direction, showed greater resistance to fracture compared to CAC and TAC. Thus, given the changes in the approach of endodontic access, it is necessary to evaluate the remaining tooth as well as the planning of root canal preparation and the choice of the restorative protocol individually, since they have a direct influence on the prognosis.

Conclusions

In endodontic treatment with Truss access cavities, reciprocating instruments with lower taper promoted less root canal transportation. Also, Truss access cavities resulted in higher fracture resistance values, but a higher percentage of voids and remaining filling material was observed.

Acknowledgments

We gratefully acknowledge the financial support by the Coordination for the Improvement of Higher Education Personnel (CAPES, Brazil, nº33002029032P4) and São Paulo Research Foundation (FAPESP, Brazil, nº2018/14450-1). The authors declare no conflicts of interest related to this study.

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