Australian Endodontic Journal
The Journal of the Australian Society of Endodontology Inc., the Australian and New Zealand Academy of Endodontists and the Asian Pacific Endodontic Confederation

Aust Endod J 2021; 47: 493–498

ORIGINAL RESEARCH

Influence of dental crown topography on fracture resistance of premolars with MOD preparation and subjected to different restorative protocols

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Keywords
endodontically treated teeth, fracture resistance, premolar, zirconia post.

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doi: 10.1111/aej.12511

(Accepted for publication 18 March 2021.)

The authors deny any conflict of interest.
All authors have contributed significantly. All authors are in agrément with the manuscript.

Abstract

To evaluate whether dental crown topography influences the fracture resistance of premolars treated endodontically and with MOD preparation subjected to different restorative protocols. Sixty-four human premolars with one or two roots in equal numerical proportions (*n*) were selected and randomly divided into four groups (*n* = 8): (S = single-rooted; D = double-rooted) SS: sound single-rooted; SNR: endodontics (E) + MOD cavity preparation; SR: E + MOD + resin restoration (RS); SP: E + MOD + RS + horizontal zirconia post (ZP); DS: sound double-rooted; DNR: E + MOD; DR: E + MOD + RS; and DP: E + MOD + RS + ZP. After allocation to the groups, the samples were thermocycled and then subjected to the fracture resistance test. Failures after the fracture test were classified as irreparable (with pulp floor fracture) or reparable (without pulp floor fracture). Data were analysed using one-way ANOVA and the Tukey test ($\alpha = 0.05$). Single-rooted premolars were more resistant to fracture than double-rooted premolars. The restorative treatment using a horizontally transfixed zirconia post improved fracture resistance, resembling that of a healthy tooth.

Introduction

The fracture resistance of a tooth is directly related to the amount of remaining coronal tissue (1). The loss of important structures, such as marginal ridges and pulp chamber roof, tends to increase cusp deflection under masticatory loads (2,3).

Deflection of the cusp can result in the development and propagation of microcracks over time and, in extreme cases, cause fracture of the dental crown (4,5). Therefore, the definitive restorative procedure is important to recover the anatomical features and function of the tooth and consequently reduce the mechanical fatigue on the cusps (6).

According to Suliman *et al*. (7), Tantbirojn *et al*. (8) and Kim and Park (9), the degree of cusp deflection is correlated to numerous factors, such as the restorative technique, the polymerisation contraction power of the restorative material and the shape and size of the cavity to be restored. For Cavel *et al*. (10), the anatomical topography of the dental crown directly influences its fracture susceptibility. In the same year, Tjan and Whang (11) found that resistance to fracture of endodontically treated teeth is directly related to the remaining tooth structure, especially correlated with the distance between cusps (in the buccal-lingual direction). The identification of these factors can help modify operative treatment practices, preventing or reducing the chances of fractures.

Accordingly, the present study aims to evaluate whether the topography of the dental crown influences the fracture resistance of premolars with MOD preparation and subjected to different restorative protocols.

The initial hypothesis was that there would be no statistical difference in fracture resistance of endodontically treated single- or double-rooted premolars restored with composite resin associated or not with horizontally transfixed zirconia posts.

Methods

This study was approved by the Research Committee of the Dental School of Universidade Federal do Rio Grande do Sul (UFRGS) and by the Research Ethics Committee of the same institution (CAAE process 85982618.0.0000.5347).

Sample selection and preparation

Sixty-four single- or double-rooted human premolars in equal numerical proportions (*n*) were used in the study. The teeth should be free from caries, non-carious cervical lesions, restorations or cracks. Double-rooted premolars should not have two fused roots.

The selected teeth had standardised tooth crown dimensions of single-rooted premolar (length = 6.5 to 8 mm; width = 6 to 7.5 mm) and double-rooted premolar (length = 8 to 9.5 mm; width = 8.5 to 10 mm). The measurement was performed with a digital calliper (Mitutoyo, Suzano, São Paulo, Brazil) at the most prominent point on the respective faces.

After cleaning procedures, the teeth were disinfected and immersed in a plastic container with 0.5% chloramine solution (Seachem Laboratories, Madison, GA, USA) for 48 h.

Experimental groups

According to the type of premolar (single- or double-rooted), the teeth were randomly divided into eight experimental groups (Table 1) by simple random sampling using Excel®.

Table 1 Layout of the experimental groups

Groups	*N*	Type of premolar	Brief description of the groups
SS	8	Single-rooted	Sound tooth (positive control)
SNR	8	Single-rooted	MOD prepared tooth + endodontics + without restoration (negative control)
SR	8	Single-rooted	MOD prepared tooth + endodontics + restoration
SP	8	Single-rooted	MOD prepared tooth + endodontics + transfixed post + restoration
DS	8	Double-rooted	Sound tooth (positive control)
DNR	8	Double-rooted	MOD prepared tooth + endodontics + without restoration (negative control)
DR	8	Double-rooted	MOD prepared tooth + endodontics + restoration
DP	8	Double-rooted	MOD prepared tooth + endodontics + transfixed post + restoration

Preparation of specimens

For individual inclusion of the teeth, PVC cylinders measuring 2 cm in height and 3 cm in diameter were used. The teeth were inserted in self-curing acrylic resin (Jet, Artigos Odontológicos Clássico, São Paulo, SP, Brazil) and centred inside the PVC cylinder, exposing the cemento-enamal joint of the tooth 2 mm above the edge of the acrylic. The specimens were stored in distilled water.

MOD cavity preparation

For MOD cavity preparations, equipment was used to standardise the inclination and movements performed by diamond tip #2143 (KG Sorensen, São Paulo, SP, Brazil) during the procedure.

Cavity preparations followed the methodology described by Cötert *et al.* (12) and Beltrão *et al.* (13). A line over the central groove was extended to the mesial surface, passing over the marginal ridge, going towards the cemento-enamal joint until reaching a height of 4 mm. This was the depth established for the preparation. The predetermined buccopalatal width in the occlusal area was extended to the mesial surface, and equally established for the proximal boxes. Diamond tip #2143 was initially positioned on the mesial surface over the central line along the predetermined length. Next, a mesiodistal box with the same width as the tip was prepared. The buccal and palatal walls were prepared to the predetermined limits so that the gingival floor could be connected to the pulp floor of the occlusal box, forming a single mesiodistal corridor. Therefore, the MOD preparation will present only the buccal and palatal walls, a common mesiodistal floor, and the pulpobuccal and pulpopalatal angles, naturally rounded by the shape of bur #2143. The bur was replaced every five cavity preparations. The superficial cavity angle received manual finishing with margin cutters #28 and #29 (SSWhite Art. Dentários Ltda., Rio de Janeiro, RJ, Brazil). In single-rooted premolars, the width of MOD preparation was equivalent to that of diamond tip #2143. In double-rooted premolars, preparation size was one and a half times that of bur #2143. The thickness of the remaining walls, both buccal and palatal, was the same for all the teeth used in the experiment (Fig. 1). MOD cavity preparation was not performed in teeth from the SS and DS

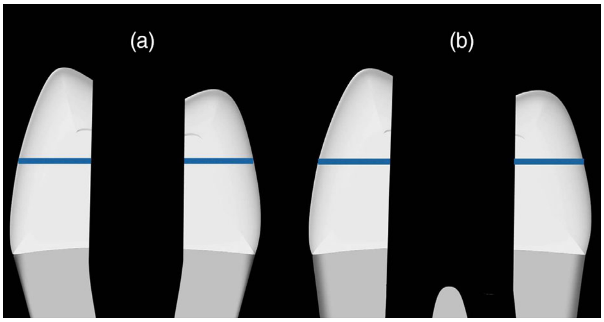

Figure 1 Schematic diagram of the MOD cavity preparation performed in single-rooted (a) and double-rooted (b) premolars.

groups. After MOD preparation, the specimens were stored in distilled water again.

Endodontic treatment

Carbide burs #02 and #04 (KG Sorensen Ind. E Com Ltda., Barueri, SP, Brazil) were used to access the pulp chamber at high speed, under water cooling. Convenience form was obtained using the Endo Z tip (Dentsply Ind. E Com Ltda., Petrópolis, RJ, Brazil).

Initially, prior to chemomechanical preparation, cervical third preparation was performed with an La Axxess® bur (SybronEndo, Glendora, USA), #35, taper 0.6, at a depth of 5 mm site of access to the canal, under irrigation with 2.5% sodium hypochlorite (Iodontosul – Industrial Odontológica do Sul LTDA, Porto Alegre, RS, Brazil). The working length for preparing the canals was 1 mm below the outlet of the foramen. The chemomechanical preparation followed the serial technique using K-files #15, #20, #25, #30 and #35 (Dentsply / Maillefer, Ballaigues, Switzerland). Irrigation was carried out with a sodium hypochlorite solution administered with a 10 ml plastic syringe and Navitip® needle with an external diameter of 0.30 mm (Ultradent Products, Inc South Jordan, Utah, USA).

After chemomechanical preparation, the final toilet was made with 17% trisodium EDTA (Biodinamica, Ibiporã, PR, Brazil) for 3 min and with agitation of #35 instrument. The canals were then washed with distilled water (Iodontosul – Industrial Odontológica do Sul LTDA, Porto Alegre, RS, Brazil) and dried with absorbent paper points (Tanari Indústria Ltda., Manaus, AM, Brazil).

For the endodontic filling, the canals were filled with gutta-percha cones and epoxy resin-based cement – AH Plus® (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland), using Tagger's hybrid technique and McSpadden® #60 compactor (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland).

Demarcation and perforation for post transfixation

Zirconia posts with 1 mm in diameter were manufactured and customised for this study. Perforations for post transfixation were performed in the central portion of the coronal middle third of the buccal and palatal walls with a diamond bur #1090 (KG Sorensen, São Paulo, SP, Brazil), at high speed, under water cooling. Bur #1090 has a diameter equal to 1.2 mm, slightly larger than that of the post, which favoured its better fit in the transfixation hole. The perforation of both sides, buccal and palatal, was made simultaneously on the same axis of insertion of the tip. The bur was changed every five cavity preparations.

Bonding of the fibreglass post in a transfixed position

First, the posts were silanised. To avoid any kind of contact with the post during silanisation, the post was fixed to a useful wax sheet in a vertical position by one of its ends. The following procedures were performed according to the manufacturer's instructions: (i) cleaning of the posts with 96% alcohol and drying with air jets; (ii) application of a silane layer (FGM Produtos Odontológicas, Joinville, SC, Brazil); (iii) drying at room temperature followed by the application of air jets, at a distance of 15 cm, for 1 min; (iv) application of a thin layer of Singlebond Universal adhesive (3M ESPE, St. Paul, MN, USA) and photoactivation with Bluephase G2 (Ivoclar) for 20 s; (v) conditioning of enamel and dentin in the transfixation holes with 35% phosphoric acid (Dentisply Ind e Com. Ltda, Petrópolis, RJ, Brazil) for 15 s, washing for 20 s and drying with air jets; (vi) application of the Singlebond Universal adhesive in the transfixation holes, pulp chamber, and cavity preparation (half of its height), drying for 5 s and photoactivation for 20 s; (vii) insertion of Bulkfill flow resin (3M ESPE, St. Paul, MN, USA) in the transfixation holes, insertion of the post in the transfixation holes and photoactivation for 40 s; (viii) Bulkfill flow resin application in the pulp chamber and cavity preparation (half of its height) and photoactivation for 40 s.

Restorative procedure

The definitive restorative procedure was performed from middle part of the cavity preparation to the occlusal plane. All teeth, with or without transfixed posts, were filled from the pulp chamber to the middle portion of the preparation with Bulkfill flow resin, to a thickness of approximately 4 mm.

The occlusal portion was restored with composite resin Z350 (3M ESPE, St. Paul, MN, USA) with the following protocol: (i) conditioning with 35% enamel phosphoric acid (30 s) and dentin (15 s), washing for 20 s and drying with air jets; (ii) application of Singlebond Universal adhesive actively for 20 s, drying for 5 s and photoactivation for 20 s; and (iii) application of Z350 resin by the incremental technique (2 mm each) in the MOD cavity preparation and photoactivation for 40 s per increment.

After the restorative procedure, the specimens were placed back in distilled water and kept in an oven at 37°C for 48 h.

Mechanical compression test

After 48 h, the specimens were initially thermocycled between 5°C and 55°C in 500 cycles. Then, the fracture resistance test was carried out on a universal testing machine EMIC DL – 2000 (São José dos Pinhais, Paraná, Brazil). A 10 kN load cell was selected and the speed was 0.5 mm min^{-1}.

A steel cylinder measuring 7.5 mm in diameter and 16 mm in length was applied to the inclined planes of the intercuspid surface of the occlusal surface of the specimen, in the mesiodistal direction, in contact with the cusps (buccal and palatal) rather than with the restorative material. Compressive stress was applied parallel to the long axis of the tooth until it fractured. The maximum fracture resistance (rupture) was recorded in Newtons.

Afterwards, the teeth were visually examined with a magnifying glass at 4X magnification to assess the dental fracture classified as follows: (i) irrecoverable (pulp floor fracture; (ii) recoverable (cusp fracture without involvement of the pulp chamber floor). Irrecoverable fracture was considered when the tooth was split into two parts at the level of the pulp floor of the cavity, regardless of whether the direction was buccal/palatal or mesial/distal.

Statistical analysis

The Shapiro–Wilk test was used to assess the normality of the data. One-way ANOVA, followed by Tukey's multiple comparison test (α = 5%) (SPSS 13.0, SPSS Inc., Chicago, Illinois, USA) was used to compare the groups.

Results

Table 2 shows that teeth with a root restored with a post had the highest mean, differing statistically from the other groups of restored teeth.

Table 2 Means and standard deviations of fracture resistance of teeth in Newtons (N) in the different experimental groups

	Dental crown topography	
Groups	Single-rooted premolar	Double-rooted premolar
Control+	1619.3 ± 607.5^{Aa}	988.9 ± 189.4^{Ab}
Control−	524.9 ± 330.3^{Ba}	373.4 ± 103^{Ba}
Restored	803.3 ± 190.3^{Ba}	507.7 ± 152.7^{Ba}
Restored + Post	1438.8 ± 53.45^{Aa}	1226.2 ± 45.01^{Cb}

Means ± standard deviations followed by different uppercase letters in the column and different lowercase letters in the row differ significantly according to one-way ANOVA, followed by Tukey's test, at the 5% significance level.

Table 3 shows that the groups with horizontally transfixed zirconia posts (MP and PP) exhibited 100% recoverable fractures.

Discussion

The initial hypothesis of the present study was rejected, as there was a statistical difference between single-rooted and double-rooted premolars treated endodontically and restored with composite resin associated or not with zirconia posts in the horizontal position (Table 2).

Dental fracture has been reported as the third leading cause of loss of restored teeth (14). Regarding resistance to dental fracture, *in vitro* mechanical fracture tests are performed to check the influence of restorative materials (15) and cavity preparations (16).

The use of premolars was based on the studies by Wu *et al*. (17) and Bianchi *et al*. (18), as this dental group presents an unfavourable anatomical configuration whose inclination of the cusps makes them more susceptible to fracture when subjected to occlusal loading, relative to the other posterior teeth.

MOD cavity preparation was performed on premolars for *in vitro* simulation of a clinical situation in which the cusps become more susceptible to deflection in the absence of marginal ridges. Schwartz and Robbins (19) found that the deflection of premolar cusps under occlusal load is greater in teeth treated endodontically and with MOD preparation. The pulp chamber roof, in an MOD preparation, becomes the closest 'link' between the cusps, absorbing and assisting in the distribution of masticatory and functional tensions throughout the dental surface (20).

According to the results obtained, healthy premolars had an average fracture load was 1619.3N for healthy single-rooted premolars and 988.9N for double-rooted premolars, similar to the values found by other studies, which ranged from 792.5N to 1755.3N (17,21,22,23).

Table 3 Site of dental fractures after mechanical testing in the different experimental groups

Groups	Fracture at the dental cusp level (recoverable)	Fracture at the pulp floor level (irrecoverable)
MS	100% (8)	0% (0)
MNR	12.5% (1)	87.5% (7)
MR	25% (2)	75% (6)
MP	100% (8)	0% (0)
PS	100% (8)	0% (0)
PNR	0% (0)	100% (8)
PR	12.5% (1)	87.5% (7)
PP	100% (8)	0% (0)

This variability in values may be due to methodological differences, such as sample preparation, storage method and the type of tooth and type of device used in the compressive loading applied in the fracture resistance test.

According to Coelho de Souza *et al.* (24), the loss of dentinal structures weakens the dental crown and may compromise its resistance to fracture. This can be verified in teeth treated endodontically, with MOD preparation and without restoration (negative control), and in those restored only with composite resin, which also showed lower values of resistance.

Regarding the influence of dental topography, the distance between cusps in double-rooted teeth was greater than in single-rooted teeth and fracture resistance was lower. In the study by Larson *et al.* (25), the authors found that prepared teeth were more susceptible to fracture than healthy teeth, and the factor that most influenced fracture resistance was the width of the occlusal portion of the preparation. That is, with the loss of marginal ridges, the remaining dental structures are weakened due to a greater width between the unsupported cusps, thus increasing the probability of their deflection and fracture of the remaining structure (17,26). Thus, in a clinical approach, the morphological topography of the dental crown, associated with the degree of loss of dentinal structures, requires detailed planning regarding the type of rehabilitation and its prognosis.

A clinical treatment alternative described in the literature (27) that has shown good results regarding dentinal reinforcement, with total or partial recovery of dental resistance, is the transfixation of prefabricated posts during direct rehabilitation. In teeth whose restorative protocol was associated with transfixation of zirconia posts, a significant increase in fracture resistance can also be seen, which is in line with the studies by Karzoun *et al.* (28) and Aslan *et al.* (27), which also obtained excellent resistance results in teeth subjected to post transfixation.

In the studies by Karzoun *et al.* (28) and Aslan *et al.* (27), fibreglass posts were used because, according to the authors, this composition has a low modulus of elasticity similar to that of dentin, thus distributing loading forces evenly across the tooth (19). In the present study, manufactured and customised zirconia posts were used and the results were surprising, since the average fracture load was statistically equal (single root) and higher (double roots) in teeth with transfixed posts in relation to healthy teeth. This can be explained by the high modulus of elasticity, rigidity and hardness of this material (29). In 2000, Rosentritt *et al.* (30) stated that the physical and mechanical characteristics of zirconia posts can increase the structural strength of teeth.

The ideal modulus of elasticity for a post is controversial. Stiffer posts can improve the support of a coronal restoration and provide a more uniform distribution of stress, but, if overloaded, they can result in more catastrophic failure modes when compared to more flexible posts (31). In the present study, this finding referring to zirconia posts cannot be considered in cases of transfixation, since 100% of the fractures of all the teeth subjected to this treatment were at the level of the dental cusp and not at the pulp floor level. Regardless of the modulus of elasticity, the transfixed post fulfils its role of promoting mainly the strengthening of the remaining dentinal structures. Mergulhão *et al.* (32) observed that the conventional composite resin restorative procedures performed showed a higher rate of irreparable fractures, and the insertion of a horizontally transfixed post in the dental crown decreased this prevalence.

Conclusions

According to the results, it can be concluded that the topography of the dental crown correlates with the risk of fracture. The greater the distance between the cusps, the lower the resistance to fracture. The restorative treatment with the use of a transfixed zirconia post improved fracture resistance, which resembled that of a healthy tooth.

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