Effect of Partial Pulpectomy Procedure on The Fracture Resistance of Mature Permanent Maxillary Premolar teeth

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ABSTRACT:

Introduction: This study aims to evaluate the effects of pulpotomy, partial pulpectomy procedures and root canal treatment on the fracture resistance of the permanent maxillary mature premolar teeth.

Materials and methods: A total of 260 recently extracted, two-rooted, intact maxillary first premolars extracted from patients aged between 15 and 25 years. After the preparation of a mesio-occluso-distal cavity in all teeth, the teeth were randomly assigned into 4 groups: group1: MOD cavity only (-ve control), group2: pulpotomy procedure, group3: partial pulpectomy procedure, and group4: full root canal treatment "RCT" (+ve control). Coronal access cavities were performed in groups (2,3&4). In the pulpotomy procedure (group2), removal of pulp tissues was done by ultrasonics to the level of the orifice while in the partial pulpectomy procedure (group3), removal of pulp tissues was done using ultrasonics, 2mm below the orifices. Finally, in group 4, full root canal treatment was performed. Following that, MOD cavities and access cavities were filled using bonded composite. All teeth were subjected to a vertical occlusal force using Universal Testing Machine until fracture occurred. The time to fracture was recorded. The data were statistically analyzed.

Results: the fracture resistance of all groups were analyzed using one way ANOVA test, followed by Tukey's post hoc test for pairwise comparison of each group. There were significant differences among groups ($P < 0.05$). The highest mean value was recorded in the (-ve) control group while the (+ve) control group showed the lowest mean value with no significant difference between pulpotomy and partial pulpectomy groups.

Conclusion: The pulpotomy and partial pulpectomy procedures improved the fracture resistance of permanent premolars with mesio-occluso-distal cavities when compared to RCT.

Keywords: Partial Pulpectomy, Pulpotomy, Root Canal Treatment, Fracture Resistance.

INTRODUCTION:

Vital pulp therapy (VPT) is one of the minimally invasive procedures which aims to preserve pulp vitality and improve the fracture resistance of the teeth [(1)]. It has been suggested as an alternative to root canal treatment in the management of irreversible pulpitis in mature permanent teeth [(2,3)]. VPT includes different procedures such as: direct and indirect pulp

capping, partial and full pulpotomy [4]. The pulpotomy procedure involves removal of the coronal pulp tissues, while preserving the radicular ones with the aid of bioactive capping materials [5]. Since the introduction of MTA to the endodontic market, different bioceramic materials have been proposed as capping agents such as: MTA, Biodentine, Bioaggregate, ... etc. It is supplied in various forms; powder & liquid, capsules and sometimes in the form of a putty consistency [6, 7]. These materials are known for their biocompatibility, maintaining pulp vitality, antibacterial properties, and their superior sealing abilities[8].

There are many advantages for using pulpotomy as a definitive treatment not only because it maintains the pulp vitality and functions (regulating inflammatory processes, repairing or regenerating the vascularized tissues and innervation)[9]. But also, the dentin-pulp complex will continue to protect itself by the formation of a mineralized barrier against further aggression [10]. The pulpotomy procedures are less complicated, less time-consuming, less expensive, and do not involve complete radicular preparation, so less weakening of the tooth than root canal treatment (RCT) [11]. Different studies have shown that pulpotomies for adult permanent teeth have high success rates ranging between 85% to 94% [12,13,14,15,16]. Depending on the extension of pulp removal, Asgary S. et al [2] in 2018 classified pulpotomies into full, partial, or miniature. The miniature pulpotomy procedure involves the enlargement of a pulp exposure site and removal of about 1 mm of the pulp tissues while the partial pulpotomy procedure implies the removal of coronal pulp tissues to the level of healthy pulp. Furthermore, the full pulpotomy procedure is one in which all the coronal pulp tissues are removed to the level of the orifices.

In pedodontics, the partial pulpectomy can be used in treatment of irreversible pulpitis of primary teeth, in which the removal of the diseased pulp tissues extended beyond the orifices[17]. In 2019, Asgary et al[1] suggested the usage of VPT including pulpotomy and partial pulpectomy as a conservative treatment for invasive cervical root resorption.

Unfortunately, the tooth undergone root canal treatment became weaker and more prone to fracture[18, 19]. So, minimally invasive approaches have been proposed to preserve tooth structures and improve fracture resistance. Using these techniques has the potential to increase the longevity and functionality of the affected tooth. Very little research has been done to evaluate the fracture resistance of teeth that undergone full pulpotomies[20]. Within the limits of

our knowledge, there is no available research compared between pulpotomy and partial pulpectomy with regards to fracture resistance.

So, this study aims to evaluate the fracture resistance of permanent maxillary first premolar teeth treated with either pulpotomy or partial pulpectomy procedures. The null hypothesis was there would be no difference in fracture resistance of maxillary first premolar teeth treated with either pulpotomy or partial pulpectomy procedures.

Materials and Methods

Study design and sample size calculation

This in vitro study was ethically approved by the Ethics Committee of Faculty of Dental Medicine (Cairo-Boys), Al Azhar University for Research on Human Subjects Number (872/173). This study followed **PRILE** interventions guidelines[21]. The sample size was calculated based on the previous study[22] using G*Power program (University of Düsseldorf, Düsseldorf, Germany)[23] . The minimum sample size was 12 samples in each of the 4 groups, which had 95% power with a significant level (alpha) of 0.05 (two-tailed).

Selection of the teeth:

Out of 260 freshly extracted maxillary first premolars, 48 maxillary first premolars with two roots were selected in the study. The teeth were collected from the outpatient clinic of the oral and maxillofacial surgery department, Faculty of Dental Medicine (Cairo-Boys), Al-Azhar University. The teeth were extracted for orthodontic reasons. The patient ranges from 15-25 years. The collected teeth were cleaned from calculus and soft tissue remnants using ultrasonic scealar (woodpecker company, china). The teeth were disinfected using 5.25% sodium hypochlorite for 5 minutes and rinsed with distilled water for 10 minutes.

All teeth included were examined as follows: -

1- **External evaluation using a dental operating microscope (DOM)** (S2300; Zumax Medical Co, Suzhou, China) at medium range magnification at 12x for exploring caries, cracks, fracture, restoration and number of roots. 22 teeth excluded leaving 238 teeth included after this step.
2- **Radiographic evaluation using RVG**: -

Teeth were radiographed in Buccolingual and mesiodistal dimensions using RVG (Carestream Kodak RVG System 14 lp/mm, 1200 x 1600 pixels - a 70-Kvp

machine" Runyes; Unicorn Denmart, New Delhi, India" with a 0.3-second exposure time). Any teeth showing root resorption, pulp calcification and/or stones, immature apecies, root fracture and any root canal type other than type I according to Vertucci were excluded**.** 28 teeth excluded and remaining 210 teeth included After preoperative radiographic evaluation step.

3- **External measurements using a digital caliper** (Aidout Digital Caliper, Egypt) for measuring the following parameters: firstly, tooth length from buccal cusp tip to the root apex, followed by crown length from buccal cusp tip to cervical line, and finally external dimensions "buccopalatal and mesiodistal" of the crown at the cervical line. These measurements were tabulated and statistically analyzed to determine the distribution of the teeth. The selected teeth in the study were included within the one standard deviation (66 %) of the total number of the calculated teeth. The one standard deviation of the above-measured parameters was: (21 mm ± 1.98 mm), (8.52 mm ± 1.32 mm), (8.6 mm ± 1.16 mm), and (5.2 mm ± 1.16 mm) for tooth length, crown length, and finally "buccopalatal and mesiodistal" external dimensions of the crown respectively (Table no 1). Any teeth that are not fitted within these ranges (66%) were excluded from the study (Table no 2). After this step, the excluded teeth were 90 and the remaining teeth were 120 which are still in the study.

4- **Radiographic evaluation using cone beam computed tomography (CBCT):** 120 teeth were scanned using CBCT (planmeca promax ® 3D, voxel size 75µm with 90 kv, 12 ma). Prior to scanning, teeth were placed inside holes of circle mold. Then, a chemically cured acrylic resin (Acrostone, Chemically Cured Acrylic Resin) was mixed and poured into the holes of the mold. After that, the root was dipped in heated wax to a level 2 mm below the cementoenamel junction (CEJ). Then teeth were embedded in soft acrylic resin to level of CEJ. The teeth were orientated to the corresponding surfaces on the mold.

The internal dimensions "buccopalatal and mesiodistal" of the pulp at the cervical line were measured. These measurements were tabulated and statistically analyzed to determine the distribution of the teeth. The selected teeth in the study were included within the one standard deviation (66 %) of the total number of the calculated teeth. The one standard deviation of the above-measured parameters was: (3.48 mm ± 0.58 mm) (1.41 mm ± 0.46 mm) for the buccopalatal and mesiodistal dimensions of the

pulp respectively (Table no 1). Any teeth that are not fitted in these ranges (66%) were excluded (Table no 2). After the CBCT image analysis step, the excluded teeth were 36 and the remaining teeth were 84 which are ready for operative procedures.

External measurements (Mean + Deviation "+ & - "% of inclusion)				
	Tooth length (mm)	Crown length (mm)	External dimensions	
			M-D (mm)	B-P (mm)
Mean (+/-) + SD	21.7 +/- 3	8.52 +/- 2	5.2 +/- 1.75	8.6 +/- 1.75
% of deviation	66 % percent *"one stander deviation"* "included" = others: exclude			
Mean (66% deviation)	21.7 +/- 1.98	8.52 +/-1.32	5.2 +/- 1.16	8.6 +/- 1.16
Internal dimensions (Mean + Deviation "+ & - "% of exclude)				
	M-D (mm)		B-P (mm)	
Mean (+/-) + SD	1.41 +/- 0.69		3.48 +/- 0.88	
% of deviation	66 % percent *"one stander deviation"* "included" = others: exclude			
Mean (66% deviation)	1.41 +/- 0.46		3.48 +/- 0.58	

Table no. (1): this table shows external measurements and internal dimensions (Mean + Deviation) (percent of exclude)

Finally, the selected teeth were stored in normal saline solution at room temperature until the time of operative procedure starting.

Operative procedures (MOD cavity preparation): -

Standard MOD cavity preparations were performed in all specimens using cylindrical carbide burs (Ela Carbide Ce0197) (5.0 mm in length and 2 mm. in diameter) attached to a high-speed handpiece (HP) (NSK TI-MAX X, High Torque, Push Bottom, Kanuma, Japan) mounted in a custom-made parallelometer device as described by Abou-Elnaga et al[24] to ensure standard MOD cavities for all teeth.

Randomization and grouping of teeth:

Following MOD cavity preparation, randomization of 48 teeth out of 84 teeth was done by giving each tooth a number from 1 to 48. The tooth numbers were submitted to Research Randomizer software (www.randomizer.org) for blind distribution of the selected patients in each group. Then, the remaining 36 teeth were given numbers and stored as a reserve for any teeth that failed during the procedures, which replaced any teeth that failed during the procedures.

Group 1: MOD cavity group "negative control":

MOD cavity preparation without access cavity preparation and left as a negative control group.

Group 2: Pulpotomy group: (Complete removal of coronal pulp tissue)

Access cavity preparation was done by initial penetration and deroofing of the samples were done using No. 2 round bur (SS White Burs, Inc, New Jersy, USA) mounted on high-speed handpiece with coolant. Refinement and finishing of the access cavity walls were done using Endo-Z bur (Dentsply Maillefer, Ballaigue, Switzerland), then pulp excavation to the level of the orifices was performed using an ultrasonic tip (ED4D, Woodpecker Company, China). Placement of 2 mm of the premixed bioceramic putty (Well-Root™ PT, Vericom, Koria) to the orifices of the canals using a MAP system (Produits Dentaires SA, Switzerland) was done and condensed with plugger size 40# (FANTA Dental, China) and bond brush "small size". After that wet cotton was placed on the surface of bioceramic putty, left for 10 min untill initial setting according to manufacture instruction. Checking on initial setting by endodontic explorer and level/amount of packing by exposing radiographs (Carestream Kodak RVG System. 14 lp/mm, 1200 x 1600 pixels) . **Figure (1)**

Group 3: Partial pulpectomy group:

Access cavity preparation and pulp excavation to the level of the orifices was done as mentioned previously in group 2. Then extend the pulp excavation using an ultrasonic tip 2 mm below the orifices. Placement of 2 mm of the premixed well root bioceramic putty below the orifices of the canals using a MAP system was done and condensed with plugger size 35# (FANTA Dental, China) and bond brush "small size". Leaving the bioceramic putty to the initial set, checking on the initial set and packing as mentioned in group 2. **Figure (2)**

Group 4: RCT group "positive control":

Access cavity preparation and pulp excavation to the level of the orifices was done as mentioned previously in group 2. Achievement of straight-line access and convenience form was done. Canal negotiation and patency was done using a size #10 and #15 K file (Mani Inc., Tochigi, Japan). The working length was estimated by CBCT and confirmed by placing a size #15 K file. Mechanical preparation was performed using Fanta Pepsi Gold Rotary Files (Fanta, China) according to the manufacturer's instruction. The preparation was finished at a size corresponding to 30#. Canals were intermittently irrigated throughout instrumentation. Then A size #30 of 0.4 tapered master cones (Dentsply Maillefer, Ballaigues, Vd, Switzerland) was fitted into the canals and confirmed by exposing radiographs. Then, the canals were dried using paper points size #30 (Dentsply Maillefer, Ballaigues, Vd, Switzerland). A resin-based root canal sealer (Ad seal Meta, Biomed, Cheongju, South Korea) was mixed. The canals were obturated with gutta percha points, size 30# using the lateral compaction technique. Excess

gutta percha was removed from the pulp chamber using a hot instrument. The access cavities were cleaned of remnants of gutta percha using handle excavators and cleaned of sealer using a wet cotton pellet.

Restoration of the specimens:

Prior to restoration of the specimens, the specimens were dried using an air/water syringe. Then, A tofflemire matrix were placed around the teeth and adapted by tightening of the tofflemire screw. The enamel surface was etched with 37 % phosphoric acid (Meta Biomed Co.Ltd. Meta Etchant) for 30 s. After that, the etched surfaces were rinsed for 20 sec and dried using an air/water syringe. A bonding agent (Solobond M. Voco. Germany) was applied to the prepared surfaces with a small sized micro-brush (Bibodent, purple, Micro Sized Microbrush) in compliance with the manufacturer's instructions then thinned a with gentle air stream from the air/water syringe, then light cured for 20 s using a LED curing device (Elipar Freelight 2, 3m Espe, Seefeld, Germany). Flowable composite (x-tra base bulk fill flowable composite. Voco.. Germany) was placed in first 2 mm increment on gingival floor of the proximal boxes of all teeth. Then inject inside access cavity till fill access cavity space as in group 2, 3, 4 then light cured for 40 s occurred. After that, the rest of the cavity was filled with packable composite resin (Polofil Nht. Voco. Germany) to the level of the occlusal surface with preservation of the occlusal anatomy. The composite was applied in 2 mm increments; each increment was light cured for 40s. The matrix band was removed, and the restoration was finished using a fine diamond bur (Diamond FG Dental Burrs Flame (Extra Fine)).

After that all specimens were stored in 100% humidity at 37°C for 24 hours to be ready for testing.

		Step	Cause of exclusion	No. excluded
1	Pre-operative excluded samples	DOM exploration step	Teeth having one root	15
2			Teeth having caries, deep cracks, fracture or restoration	7
3		Radiographic evaluative step “using RVG”	Teeth having pulp calcification and pulp stone	3
4			Teeth having immature apecies	3
5			Teeth having root fracture	3
6			Teeth have any type except type I according Vertucci classification	19
7		External measurements	Teeth excluded due to larger or smaller tooth length	42
			Teeth excluded due to larger or smaller crown length	27

8			Teeth excluded due to larger or smaller external dimensions “buccopalatal & mesiodistal” at cervical line	21
9		Internal measurements step “using CBCT”	Teeth excluded due to larger or smaller internal dimensions	36
10	Intra-operative excluded samples		Teeth excluded due to faults or destruction occurred during operative procedures	30
	Total			206

Table no. (2): Different causes and numbers of excluded teeth within the study

Fracture test of the specimens

All specimens were individually mounted in a computer-controlled materials testing machine (Instron Industrial Products, Model 3345; Norwood, Ma, Usa,) (load cell of 5 kN) and data were recorded using computer software (Instron® Bluehill Lite Software). specimens were secured to the lower fixed compartment of the testing machine by tightening the screws. A long stainless-steel rod with rounded tip (3.8 mm diameter) was positioned on the center of occlusal surface of the specimens touching the inclined surfaces of both buccal and lingual cusps and composite restoration occlusally. The samples were submitted to a vertical compressive force loaded at a crosshead speed of 1 mm/min. parallel to the long axis of the tooth until fracture occurs. The load at failure manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using computer software (Bluehill Lite Software Instron® Instruments). The load required to fracture of the specimen was recorded in Newton.

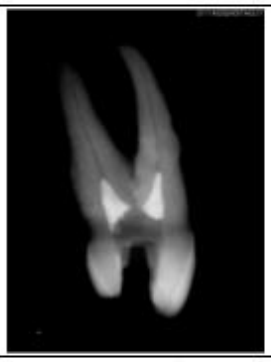
Statistical analysis of the data:

Data was collected, tabulated and statistically analyzed in several steps. Values were presented as number & percentages, also, mean and range values. Data were explored for normality using Kolmogorov-Smirnov test of normality were normally distributed of data. Therefore, one way analysis of variance (ANOVA) test was used to compare between groups, followed by Tukey’s post hoc test for pairwise comparison. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with SPSS 23.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows.

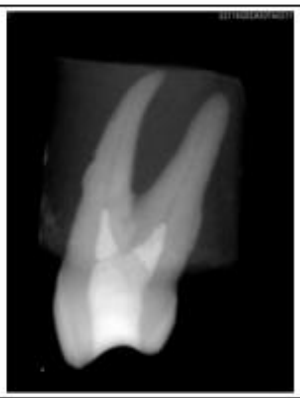
Figure (1): show steps of Partial Pulpectomy group (PP)

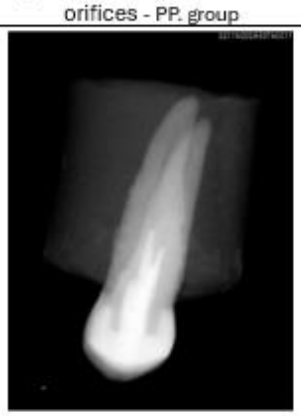
1- Access cavity - PP. group

2- Trephination 2mm beyond canal orifices- PP. group



3 - Placement of bioceramic putty 2 mm beyond canal orifices - PP. group



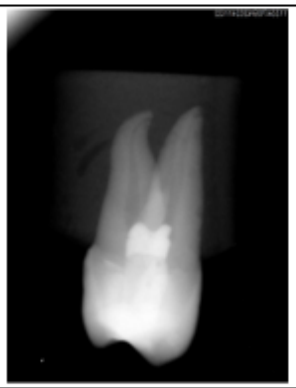


4- Post-operative (after placement of final restoration) PP. group

Figure (2): show steps of Pulpotomy group (PP)

1- Access cavity + trephination by ultrasonic-pulpotomy group

2- Placement of bioceramic putty 2 mm above canal orifices - pulpotomy group



3- Postoperative - pulpotomy group

Results:

Comparison between the fracture resistance of the different treatment modalities: The highest fracture resistance for Group 1 was (1045.11±144.90), followed by Group 2 was (934.44±106.46), then Group 3 was (900.74±156.06) and the lowest Group 4 was

(671.91±120.54). There was a statistically significant difference between groups (P=0.001). (Figure 1).

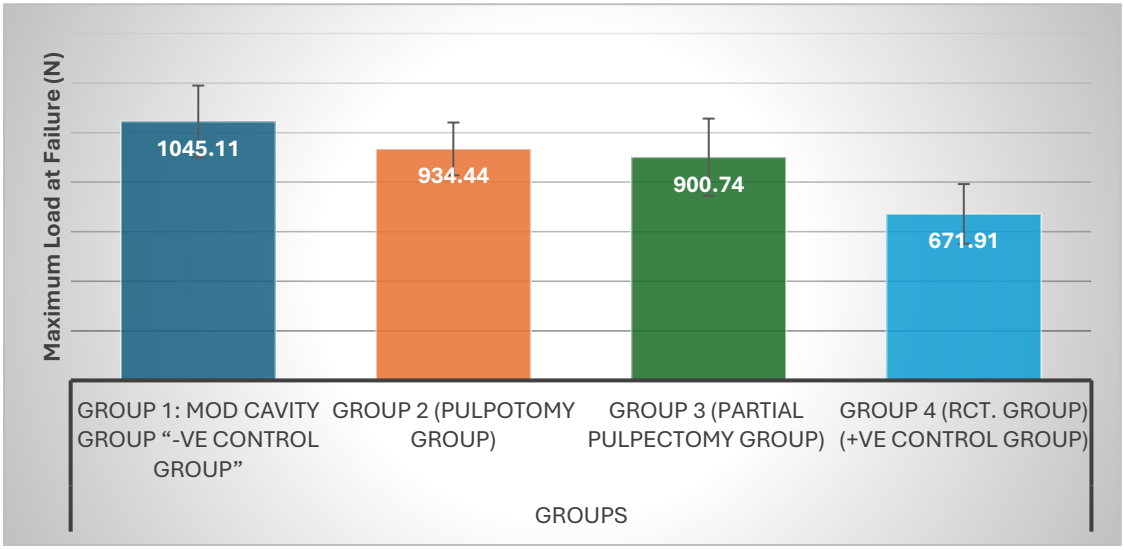


Figure (1): Showing the mean ± SD values, for the comparison between different groups regarding Maximum Load at Failure (N).

Comparison between the fracture resistance of all groups with each other revealed the following: There was a statistically significant difference between group 1 and group 2 (p = 0.048), group1 and group 3 (p = 0.011), group 1 and group 4 (p = 0.001), group 2 and group 4 (p = 0.001), finally group 3 and group 4 (p = 0.001). There was no a statistically significant difference between group 2 and group 3 (p = 0.539).

Discussion

Vital pulp therapy is becoming a more commonly used procedure in treating adult teeth suffering from irreversible pulpitis such as pulpotomy and partial pulpectomy. The pulpotomy procedure involves complete removal of the coronal pulp tissue [25], while further removal of the radicular pulp tissue can be considered a partial pulpectomy. Previous studies have established that endodontic treatment inherently results in weakness of the remaining tooth structure [26]. Less aggressive procedures like pulpotomy and partial pulpectomy could improve fracture resistance of the teeth.

The aim of the study was to evaluate the fracture resistance of permanent maxillary first premolar teeth treated with either pulpotomy or partial pulpectomy

The null hypotheses were, there would be no difference in fracture resistance of maxillary first premolar teeth treated with either pulpotomy or partial pulpectomy.

Three hundred freshly extracted maxillary first premolars were collected for use in this study. They were extracted for orthodontic reasons. Maxillary premolars were selected due to the fact that they are prone to cuspal fracture and because of ease of acquisition [27,28,29].

The teeth were collected from patients with ages ranging between 15 and 25 years, to ensure root maturity and to minimize variation in the nature of the dentin due to age related changes such as secondary dentine formation, sclerotic dentin deposition and age-related cracks [30,31].

Most research done in this field is not clear on the method by which teeth are excluded [32, 33,22]. In an effort to minimize bias, stringent exclusion of teeth was done from an initial total of 210 selected teeth. Exclusion was done initially by tooth length, followed by crown length, followed by external dimensions, and finally internal dimensions. One standard deviation was used to calculate the teeth to be included (66 %) and excluded (34 %) from the available pool of teeth.

Standardized Class II MOD cavities were done using a parallelometer device [24] to closely mimic the clinical situation and furthermore to eliminate the effect of marginal ridges on the strengthening of the cuspal deflection. The bur used was replaced after 4 preparations. This practice is common when doing research in this field [24,32 ,33 ,34].

Regarding the choice of the capping material, well-root bioceramic putty was selected because of its availability in the market and ease of placement [35,36]. With regards to tooth restoration, within this field of study, some research restored the teeth using bonded composite after pulpotomy procedure [37, 33, 32]while other researches was shows not to restore them[37,33]. In this study, our target was not to evaluate different restorative materials but to evaluate the effect of pulpotomy or partial pulpectomy procedures on the teeth, so it was not necessary to create a group without a final restoration. Furthermore, restoration with bonded composite closely mimics the clinical situation.

In this study, Static compressive loading was done to evaluate fracture resistance. Unfortunately, dynamic testing was not available. Furthermore, all the research done in this field has been done using static compressive loading tests [38, 33,24 ,34]. The diameter of the sphere head used during testing was 3.8 mm. to allow for adequate contact with the cuspal inclines during testing. This is similar to another research done in the field [38].

Regarding the results, when comparing the fracture resistance of pulpotomy procedure (934 +/- 106.46) and partial pulpectomy procedure (900.74+/- 165.06), there was no significant difference (P= 0.539). Although partial pulpectomy involves more removal of tooth structure, it seems it does not have an effect on the resistance to fracture. On review of the literature, the research in this field is lacking, no research is available in which the fracture resistance of pulpotomized teeth was compared to partial pulpectomy or even to fully root canal treated teeth. The only research available, in which the fracture resistance of pulpotomized teeth were evaluated was by Ghahramani Y et al 2021[33]. They evaluated the effect of combination of different materials used for pulpotomy such as MTA and CEM cement with different restorative materials such as amalgam, conventional composite resin and high viscosity bulk-fill giomer on the fracture resistance of pulpotomized teeth. In this study, there was no significant difference between the materials used for pulpotomy. With regards to the restorative materials, amalgam was the weakest material.

It is worthy to mention that both groups showed significantly higher fracture resistance than the positive control group (fully root canal treated teeth). This shows that minimally invasive techniques improve the fracture resistance. These results make sense as it is been established previously that more aggressive root canal preparation will result in weaker fracture resistance [39, 40].

On the other hand, both groups also showed significantly lower resistance to fracture when compared to the negative control group (MOD cavity only). This an expected result because even though the pulpotomy and partial pulpectomy procedures are minimally invasive, but they are still invasive.

It is clear that minimally invasive techniques like pulpotomy and partial pulpectomy are less aggressive and more root friendly. Using these techniques have the potential to increase the longevity of the affected teeth with regards to functionality. Within the parameters of the study, there was no significant difference between pulpotomy and partial pulpectomy, and the null hypnosis was accepted.

Conclusion

Both pulpotomy and partial pulpectomy procedures improved the fracture resistance of permanent premolars with mesio-occluso-distal cavities compared to the root canal-treated teeth, which did not improve it.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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