EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 861:870, January, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 07-11-2023 • Accept Date : 25-12-2023 • Available online: 10-01-2024 • DOI : 10.21608/EDJ.2023.247133.2775

COMPARATIVE EVALUATION OF THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS AFTER DIFFERENT ACCESS CAVITY DESIGNS-ROOT CANAL TAPER COMBINATIONS

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ABSTRACT

Purpose: This research compared the fracture resistance of endodontically treated premolars with traditional and conservative access cavity designs and different root canal tapers (0.04 and 0.07).

Materials and methods: In the current study, ninety extracted human mature intact maxillary first premolars with comparable sizes were chosen. The teeth were randomly assigned into seven groups, one control group (n =30) and six test groups (n=10 each) according to the access cavity design and instrumentation system, Group 1 (control group): Intact teeth with no treatment, Group 2: Teeth with prepared TAC with no instrumentation, Group 3: Teeth with prepared CAC with no instrumentation, Group 4: Traditional access cavity/ Primary WaveOne gold, Group 5: Traditional access cavity/ XP-Endo Shaper, Group 6: Conservative access cavity/ Primary WaveOne gold, and Group 7: Conservative access cavity/ XP-Endo Shaper. Filling of the root canals was done using gutta-percha/Endosequence BC sealer in lateral condensation technique. The force required to fracture each tooth was measured and recorded in Newtons by loading it in the universal testing machine until fracture occurred. Analysis of fracture resistance data was done using Two-Way ANOVA test, followed by Tukey test for multiple pairwise comparisons. Differences among groups were considered significant if p-value ≤0.05.

Results: The control group had the highest fracture resistance while group 4 (Traditional access cavity/WaveOne gold) recorded the lowest value. The difference among the groups was statistically significant ($P < .05$).

Conclusions: Endodontically treated maxillary premolars show significantly reduced fracture resistance when prepared with greater taper instruments, regardless of their access cavity design.

KEYWORDS: Conservative access cavity, endodontically treated premolars, fracture resistance, root canal taper, traditional access cavity.

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INTRODUCTION

The fracture resistance of root canal-treated teeth is lower compared to untreated teeth[1-5]. This is because the root canal treatment (RCT) process can cause tooth breakage because of insufficient dental structure left after access cavity preparation and caries removal. In addition to that, dentine is often lost because of over-removal during the shaping and instrumentation processes. [3, 5-8]. Furthermore, it has been suggested that the amount of remaining dentine is necessary for the health and durability of root canal-treated teeth. [5]

Access cavity preparation is a crucial step for effective RCT. [9] To reach the root canal orifice(s) and reduce the likelihood of making a mistake, an access cavity is prepared by removing the pulp chamber roof. [9-11]. In the endodontic literature, preserving pericervical dentin (4mm above and 4mm below the alveolar bone crest) is essential for strengthening endodontically treated teeth. [12]

Traditional access cavity (TAC) creates a straight pathway to the canals by eliminating any decay and/ or any previous restoration. This pathway reaches the apical constriction by removing any cervical dentin projections from the canal orifice while conserving the remaining sound tooth structure. [2, 13, 14]. The convenience form used for this procedure allows for easy access to the canal's orifices, conventional coronal flaring, and direct access to the apical foramen.

Modern dentistry is using a minimally invasive approach to prevent or treat dental pathosis while maintaining as much of the dental tissues as possible [15]. Recently, there have been great advancements in endodontic technology. These advancements have led to the development of new strategies that are based on minimal invasive concepts during root canal treatments. These latest technological advancements include improved optics for magnification and illumination, and 3D diagnostic aids, such as CBCT. These modern strategies are designed to perform less invasive and more efficient endodontic procedures. They include access cavity designs, root canal instrumentation using nickel-titanium metallurgy, motions, and file design. Additionally, modern approaches have been developed depending on minimal invasive procedures for various steps of endodontic therapy, including access cavity designs.

Minimally invasive dentistry is based on the idea that the tooth's original structure should be maintained whenever possible. This is accomplished by limiting the amount of dentin removed during the shaping process, keeping the roof of the pulp chamber, and not over-flaring the canal orifices. [16]. By protecting the pericervical dentin, the tooth's mechanical stability is maintained, which helps to prolong its lifespan and improve its functionality [11, 13, 17]. However, this approach can create challenges when treating the root canals. A relatively modern cavity design may make it difficult to irrigate, instrument, and fill the canal properly. Additionally, an undersized cavity can increase the likelihood of errors during the endodontic procedure[18].

The conservative approach to cavity design entails partially removing the pulpal roof while leaving the pulp horns intact and slightly adjusting the cavity walls. Conservative access cavity (CAC) only allows for viewing the canal orifices from different angles. The pulp chamber is entered through the central fossa of the occlusal surface and just extended laterally enough to detect the canal orifices [10].

Conservative truss access cavity include preparing of two occlusal cavities that are joined by an enamel/dental bridge [19]. The canal orifices of multi-rooted teeth can be reached directly with this apparatus and is also referred to as "orifice-directed dentine conservation access" [20].

Minimally invasive endodontics, which involves creating smaller access openings, it has been proposed that the chance of root fracture is decreased by employing minimal instrumentation with an apical diameter ranging from 0.2mm to 0.4mm with a taper of less than 6%.[21, 22].

Rotary Ni-Ti systems help remove debris from canals, and the use of various file designs, metallurgical alloys, and rotational motion with higher instrument tapers results in cleaner canal walls. This reduces concerns about bacterial elimination in the canals. However, there is a risk of much removal of radicular dentin due to greater instrument taper, which is a concern [18].

WaveOne gold (WOG) is a single-file that moves in a reciprocating manner with alternating movement of anticlockwise by 170 degrees and 50 degrees clockwise [23]. The characteristic gold color of WOG files is due to post-production heat treatment procedure. The process of continuously heating and cooling the raw metal results in not only the gold appearance, but also much increased strength and flexibility. [24].

XP-Endo Shaper (XPS) is a single-file system which rotates continuously. It is a unique instrument with a snake-like shape and an adaptive core made of thermomechanically treated Ni-Ti alloy termed as Max-Wire (Martensit-Austenite-electropolish-fileX) that has superelasticity and shape memory. At room temperature, the instrument is straight in its martensitic phase (M-phase), but when exposed to the intracanal temperature, it transforms to the austenitic phase (A-phase) and becomes curved. When entered the root canal, the instrument exhibits a shape memory effect, changing from M-phase to A-phase, and has superelasticity. After being cooled, the file is in its M-phase with a taper of 0.01, Warming it to 35 degrees Celsius increases the taper to 0.04. [25].

Numerous studies have analyzed how the resistance to fracture of teeth treated with root canal therapy changes based on various access cavity designs and root canal instrumentation with varying tapers. However, there is limited research on the combined effect of canal taper and conservative access cavity designs on fracture resistance. So, this study aims to assess the influence of various instrumentation tapers and access cavity designs on the fracture resistance of maxillary premolars that have undergone endodontic treatment.

MATERIALS AND METHODS

Ninety maxillary first premolars with distinct buccal and palatal roots extracted for orthodontic purpose were chosen. Only those with similar crown external dimensions were selected, the dimensions of the crown of each selected tooth were measured using digital caliper (Mitutoyo Co., Tokyo, Japan): 7.84 ± 0.66 mm buccolingually and 5.84 ± 0.96 mm mesiodistally at the cervical line and collected from patients of age ranges from 18 to 23 years old. Teeth that already had previous root canal therapy, root caries, cracks, internal or external resorption, canal obliteration or immature teeth were not included.

The teeth were immersed in a 5.25% sodium hypochlorite solution (NaOCl) (Clorox Co., 10th of Ramadan, Egypt) for 10 minutes and then manually cleaned to remove any calculus. Afterward, they were kept in distilled water until intentionally fractured.

The purpose of the study was explained to the patients and informed consents were obtained to use their extracted teeth in the research according to the guidelines adopted by the Research Ethics Committee at Faculty of Dentistry, Tanta University.

The teeth were randomly assigned into seven groups: one control group (n=30) and six test groups (n=10 each). The groups were assigned based on the access cavity design and instrumentation system.

Group 1 (control group): Untreated teeth that remained intact until the fracture resistance test.

Group 2: Teeth with prepared TAC with no instrumentation

Group 3: Teeth with prepared CAC with no instrumentation

Group 4: TAC / Primary WaveOne gold

Group 5: TAC / XP-Endo Shaper

Group 6: CAC / Primary WaveOne gold

Group 7: CAC / XP-Endo Shaper

Traditional access cavity preparation:

TAC was prepared in an oval shape using round bur no. 3 (Dentsply Maillefer, Tulsa, OK, USA). The cavity was extended buccolingual using EndoZ bur (Dentsply, Maillefer, Baillagues, Switzerland) to ensure removal of the entire pulp chamber roof and maintain direct pathway without any occlusal interference (Fig. 1A).

Conservative access cavity preparation:

For CAC, the occlusal surfaces of premolars were entered 1 mm buccal to the central fossa, and then extended laterally preserving portion of the pulp chamber roof (Fig. 1B).

After the access cavity was prepared, a #15/0.02 taper hand stainless steel K-file (Mani Inc., Tochigi, Japan) was inserted in each root canal until its tip was just seen at the anatomical tip. 1 mm was then subtracted from this measurement visually to get the working length (WL).

Root canal instrumentation:

Group 4,6: Primary WaveOne gold (Dentsply, Maillefer, Switzerland) with a size 25 and 7% taper was used in the programmed reciprocation mode for this system.

Group 5,7: The canal was prepared using XPS (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) (#30/04) in continuous rotation at 800 rpm and 1 Ncm torque.

X-Smart Plus endodontic motor (Dentsply, Maillefer) was used based on the manufacturer's recommendations and programmed mode for each file system.

During and after instrumentation, 3 mL of a 5.25% NaOCl solution was injected with a plastic disposable syringe fitted with a 27-gauge NaviTip (Ultradent Inc., South Jordan, Utah, USA). After preparing the canals, 3mL of 17% ethylene diamine tetracetic acid (EDTA) was flushed through them for 1 minute before being followed by normal saline solution and drying with paper points (DiaDent Group International, Burnaby, B.C. Canada).

For root canal obturation, a greater taper gutta-percha cone (DiaDent Group International, Burnaby, BC, Canada) according to the instrumentation system in combination with Endosequence BC sealer (Brasseler USA, Savannah, Georgia, USA)

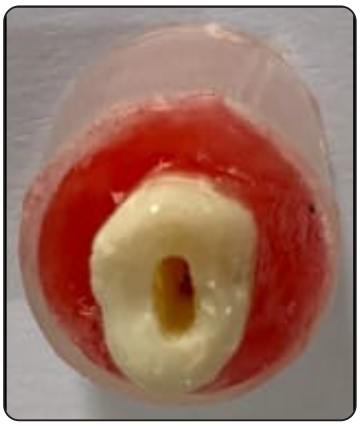

Fig. (1A): Traditional access cavity

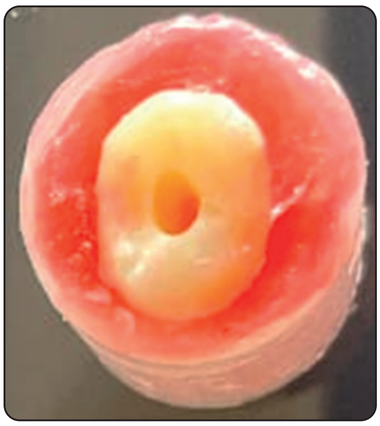

Fig. (1B): Conservative access cavity

was used in lateral condensation method. To completely fill each canal space, the master cone was coated with sealer before being put into the canal. This process was repeated with size 20, 0.02 taper supplementary gutta-percha cones until complete filling of each canal space.

Finally, the access cavities were restored using a layer of Filtek™ Z350 XT flowable composite (3M ESPE, Seefeld, Germany) over the canal orifices followed by Filtek™ Z250 XT nanohybrid resin composite (3M ESPE, Seefeld, Germany). All teeth were kept in 100% humidity at 37°C for two weeks before evaluating their fracture resistance.

Sample preparation for fracture resistance test:

To mimic the periodontal ligament, the tooth roots were covered with a thin layer of light body Speedex silicone rubber base (Coltene/Whaledent, Altstätten, Switzerland) and then embedded in a cylinder of self-cured acrylic resin 2 mm apical to the cemento-enamel junction [(26)].

To ensure that the applied force was distributed uniformly in all directions, The load was applied using a suitable designed rod, which was connected to the loading cell of the upper member of the universal testing machine (Lloyd Instruments Ltd, Fareham, UK). This rod was lowered at a crosshead speed of 1 mm/min to allow it to contact the central fossa of the tooth occlusal surface. Each tooth's maximum force of breakage was measured in Newtons (N).

Statistical analysis

The force needed to fracture each tooth was measured in Newtons, and the mean and standard deviation (mean ± SD) are reported. The statistical analysis included a Two-Way ANOVA to identify differences between groups, followed by numerous pairwise comparisons using the Tukey test, the significance level was set at $P \leq 0.05$.

RESULTS

The mean values and standard deviations of the load required to fracture the teeth of all groups are presented in Table 1.

Two-Way ANOVA revealed that the control group had the highest fracture resistance of 1276.21± 136.33, while the lowest value of 642.50±209.83 was recorded for group 4 (TAC/WaveOne gold). The difference among the groups was statistically significant ($P < .05$).

Tukey test was used for pairwise comparisons and revealed significant difference between control group versus groups 2,4,5 and 6, group 4 versus groups 2,3, 5 and 7 ($P < .05$).

TABLE (1) The mean and standard deviations of force in Newton required for fracture resistance of the test groups.

Groups	Mean	SD
Group 1 (Control Group)	1276.21^{a}	136.33
Group 2	955.20^{b,c}	89.46
Group 3	1083.60^{a,b}	175.49
Group 4	642.50^{d}	209.83
Group 5	943.08^{b,c}	45.97
Group 6	837.52^{c,d}	89.93
Group 7	1120.22^{a,b}	48.52

Mean values with different superscript letters are significantly different using Tukey test.

When comparing intact teeth to those with access cavity designs, regardless of canal instrumentation taper, the mean fracture resistance values were 1276.21±136.33, 1013.78± 169.31, and 846.93±194.64 N for control group, CAC and TAC respectively. There was a significant difference between the groups ($P<.0001$). The Tukey test showed statistically significant difference between CAC and TAC ($P < .05$), and both had a significant difference compared to the control group ($P < .05$).

When evaluating the impact of canal taper on fracture resistance of endodontically treated tooth, it is necessary to compare the canal taper with the intact control and no instrumentation groups regardless of the access cavity design. The fracture resistance values were 1276.21± 136.33, 1019.40±147.73, 1031.65±103.45 and 740.01±183.65 for intact teeth, no instrumentation, XP-Endo Shaper and WaveOne groups. Two-Way ANOVA revealed statistically significant difference ($P<.0001$). Pairwise comparisons of the groups using the Tukey test reported significant difference between control and no instrumentation groups, control and XP-Endo Shaper groups, control and WaveOne groups, XP-Endo Shaper and WaveOne groups, with P-values <.05. While no statistically significant difference was recorded between XP-Endo Shaper and no instrumentation groups ($P > .05$).

DISCUSSION

Using CAC and TAC, the fracture strength of maxillary first premolars was evaluated in this in-vitro study after different root canal preparation tapers (0.04 and 0.07 taper).

Owing to the removal of internal tooth structure during RCT, endodontically treated teeth are more likely to break than natural teeth [27]. These teeth can fracture if too much dentine is removed during the instrumentation procedure, post channel preparation, and root canal filling processes, according to a number of studies. [28-30].

Recently, maximum tooth structure preservation and conservation have contributed to the rise in popularity of minimally invasive endodontics [15]. To protect the pericervical dentin (PCD), minimally invasive endodontics reduce the size of the access cavity and root canal instrumentation [27].

Maxillary first premolars were selected for this study because loss of dentin during endodontic access cavity preparation in the presence of radicular fluting, with two thin roots and their cuspal inclines render them more susceptible to fracture under occlusal force [31, 32]. Teeth that had similar dimensions were chosen to decrease the effect of size and shape differences.

In the current study, bonded resin composite was used to reconstruct access cavities to mimic clinical procedures and allow for loading tests[33].

In this study, a statistically significant difference was recorded between the test groups and the control group with the highest mean fracture resistance value for the control group while group 4 (TAC/WaveOne gold) recorded the lowest value. This finding may be explained by the impact of excessive dentin removal during TAC preparation with complete deroofing of the pulp chambre and coronal preparation in combination with canal preparation with greater taper of 7% which in turn decreased the fracture resistance [13, 18, 34]. Also, there was no statistical difference between CAC with no instrumentation and TAC with no instrumentation groups. This was attributed to that the removal of mesial and distal marginal ridges is the primary cause of decreased fracture resistance of endodontically treated teeth [35, 36].

When the access cavity designs were compared to the control group regardless root canal preparation taper, results indicated a statistically significant difference. This could be because the preparation of access cavities weakens the tooth, making it more prone to fracture when subjected to normal chewing forces [12]. Statistically significant difference was recorded between TAC and CAC designs. This may be because of the preservation of PCD and portion of the pulp chamber roof and the soffit in CAC opposed to TAC design [35, 36].

According to the findings of the current study, TAC has lower fracture strength compared to CAC. This is consistent with the results of previous studies conducted by Krishan et al. [26] and Plotino et al. [33].

In contrast, this study's findings contradict Yuan et al.[37], Moore et al.[38], Sabeti et al.[18] Corsentino et al.[35] and Özyürek et al.[19] studies, they revealed no statistically significant differences between root canal treated teeth with conservative access and those prepared with conventional access regarding their fracture resistance. This contrary may be explained by variations in research methods which include the specific teeth being studied, the type of restoration used, the materials used in restorative treatment. Additionally, the design of the fracture test itself can also impact the results.

These findings disagreed in part with Plotino's et al.[33] where fracture resistance of teeth with CACs did not significantly vary from undamaged control teeth, whereas TACs did. This contrasting finding may be related to different methodology that involved loading the teeth at a 30-degree angle of their long axis.

Regardless of the form of the access cavity, the canal taper was compared to the no instrumentation group and the intact teeth of the control group. Previous research has shown that the control group has the highest fracture resistance values. [18, 39, 40]. This finding demonstrates the unfavorable effects of root canal preparation, in which more dentine is removed. The tension in the root dentine is increased and the fracture resistance is decreased when the taper of the file increases from 0.06 to 0.08[18, 41]. Additionally, too much taper can lead to too much dentine removal, which in turn can weaken the root and make the tooth more prone to breaking[34]. Moreover, the cervical region of endodontically treated teeth is less likely to be stressed by smaller tapered preparations than by higher tapered preparations. [22].

There is contradictory research in the endodontic literature about the influence of canal taper on tooth fracture resistance. Several studies reported that a smaller taper instrument increases the resistance to fracture compared to teeth prepared with a greater taper instrument[18,40,42-44]. While other authors reported that there is no correlation between increased instrument taper and resistance to tooth fracture [45, 46].

This study found that the canal taper and the form of the access cavity significantly affected the fracture resistance of endodontically treated teeth.

This result is supported by Sabeti et al.[18], Zandbiglari et al.[39], and Krikeli et al.[47], they found that increasing the taper of rotary instruments resulted in decrease in fracture resistance. But research of Lam et al.[48], and Hegde et al.[49] results showed that the fracture resistance of endodontically treated teeth was not influenced by an increase in taper. This controversy in results may be explained by different methodology in which different instruments in the former study while a spreader was inserted into the canal for application of vertical load until fracture occurred in the latter one.

These results were in disagreement with Jiang et al [2] and Wang et al [50], they demonstrated that the design of the access cavity had a greater influence on the durability of endodontically treated teeth than the canal taper, and that the mechanical differences between the different access cavity designs were not significant. This may be attributed to different methodology by using finite element analysis of 3D model of endodontically treated molars.

CONCLUSIONS

Within the scope of the current study, greater taper instruments lead to a marked reduction in the fracture resistance of endodontically treated maxillary premolars irrespective of their access cavity design.

Conservative endodontic access cavity in maxillary premolars can be a better option than traditional one, as it improves the resistance of endodontically treated teeth against fractures.

Limitations of this study:

It was not possible to replicate the precise oral conditions as the static vertical load used in the fracture resistance test does not simulate the dynamic load experienced during the chewing cycle in the clinical situation.

Also, using a smaller sample size of each group in this study may have prevented the presence of statistically significant differences between test groups.

Financial support and sponsorship: Nil.

Conflicts of interest: There are no conflicts of interest.

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