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Impact of Access Cavity Design and Root Canal Taper on Fracture Strength of Endodontically-Treated Mandibular Premolars (An In-vitro Study)

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ABSTRACT

Background: Endodontic-treated teeth present a higher fracture rate. The fracture strength of endodontically treated teeth is affected by access cavity design and cervical root canal dentin thickness. ***Aim:*** To compare the effect of access cavity design and two different root canal tapers in extracted mandibular premolars on fracture strength of endodontic treated teeth and remaining cervical dentin thickness. ***Materials and Methods*:** A total of (20) lower premolars were selected and divided into four groups. In group (A), five teeth were accessed traditionally and prepared by CMA rotary system. In group (B) five teeth were accessed traditionally and prepared by the M3 Pro Gold rotary system. In group (C) five teeth were accessed conservatively and prepared by CMA rotary system and in group (D), five teeth were accessed conservatively and prepared by m3 pro gold rotary system. Remaining dentin thickness through CBCT scanning and fracture strength was measured through the universal testing machine. ***Results:*** No significant difference between the removed dentin thickness of treated teeth either with M3 pro gold or CMA at coronal and middle levels; however, at the apical level, CMA showed statistically significantly lower median remaining dentin thickness than M3 Pro Gold. No significant difference between fracture resistances of treated teeth either with traditional or conservative access.***Conclusion:*** Conservative design failed to intensify the fracture resistance of mandibular premolars. Conservative cervical taper within 4% and 6% presented similar effect on cervical dentin thickness in mandibular premolars.

Keywords: conservative endodontic cavity; fracture resistance; cone beam computed tomography; traditional endodontic cavity

INTRODUCTION

Endodontic treatment is the standard protocol for infected teeth. To guarantee a successful good prognosis for an endodontically treated tooth, one of the

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preliminary steps is to prepare proper access activity to the root canal system. Adequate access cavity ensures easy localization of the canals, proper chemo-mechanical preparation, and obturation. Deficient cavity preparation complicates root canal treatment and could lead to the aberration of the original root canal anatomy. In such cases, the infection perseveres, and the treatment fails.[1]

Traditional endodontic cavity (TEC) involves straight-line pathways into the canals done by removing cervical dentin projections, and de-roofing the pulp chamber in order to reach apical constriction. Extensive removal of the tooth structure, coronal to the pulp chamber and around the canal orifices, is the most frequent cause of fracture in endodontically-treated teeth.[2,3]

The last decade has witnessed considerable evolutions for minimal intervention. In minimally invasive endodontics, conservative endodontic access cavity (CAC) is a modified design which preserves parts of the pulp chamber roof and peri-cervical dentin in order to overcome the major drawback in the traditional design. Peri-cervical dentin which is located 4 mm above and 4 mm below the crestal bone, serves in the distribution of functional stresses in teeth. Although the preserved structure may offer the benefit of improved fracture resistance, the scientific evidence for CAC remains scarce.[4,5]

Out of the root canal treatment processes, mechanical preparation is of great importance. Earlier, conventional 2% taper hand instruments were used in mechanical preparation. Then various kinds of Ni-Ti rotary and reciprocating instruments appear in the market. They excessively improved the root canal preparation due to their metallurgical properties. Therefore, nickel-titanium rotary instruments have become the main instrument for root canal preparation. Since the increased taper of these files had reached 9 %, results in aggressive removal of the radicular dentin, there were different opinions regarding the effect of increased tapered nickel-titanium rotary instruments on root fracture resistance.[6,7]

MATERIALS AND METHODS

Materials used in this study are shown in **Table (1)**. A total of non-identified 20 intact, sound, single-rooted mandibular premolar extracted teeth were selected for the study. Teeth were thoroughly washed under running water to remove blood and mucous, and scaled to remove calculus and remnants of periodontal ligaments. All teeth were scanned by CBCT and the cervical dentin thickness was measured**.**

Samples grouping

Table (1): Descriptive statistics and results of Mann-Whitney U test for comparison between dentin thickness (mm) of the two access types.

System	Root level	Traditional (n = 5)		Conservative (n = 5)		*P*-value	*Effect size (d)*
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
CMA	Coronal	0.2 (0.1-0.4)	0.22 (0.13)	0.2 (0.1-0.3)	0.2 (0.07)	0.913	0.066
	Middle	0.2 (0.1-0.3)	0.2 (0.1)	0.2 (0.1-0.3)	0.22 (0.08)	0.740	0.199
	Apical	0.1 (0.1-0.2)	0.14 (0.05)	0.2 (0.1-0.2)	0.16 (0.05)	0.549	0.335
M3 Pro Gold	Coronal	0.3 (0.2-0.4)	0.32 (0.08)	0.2 (0.1-0.4)	0.24 (0.11)	0.233	0.78
	Middle	0.4 (0.2-0.4)	0.34 (0.09)	0.3 (0.1-0.4)	0.28 (0.13)	0.432	0.475
	Apical	0.2 (0.1-0.4)	0.26 (0.13)	0.3 (0.2-0.3)	0.26 (0.05)	0.913	0.066

**: Significant at P ≤ 0.05.*

The selected teeth were divided into four equal groups, with five samples in each group prepared as follows: Group(A): samples were accessed traditionally and prepared by CMA rotary system. Group(B): samples were accessed traditionally and prepared by M3 pro gold rotary system. Group(C): samples were accessed conservatively and prepared by CMA rotary system. Group (D): samples were accessed conservatively and prepared by M3 pro gold rotary system.

Teeth Preparation

Each root within each sample was marked by indentations using a size 1 inverted cone bur on all aspects (buccal, mesial, distal, and lingual) at three levels (3mm, 5mm, and 7 mm)[8], as shown in **figure 1**. The roots were covered with wax and embedded in putty filled blocks of size "5cm*8cm". Samples were arranged as three teeth in each block.

Figure (1): Tooth Sample with indentations made on root surface at 3, 5, 7 mm from the apex.

Preoperative CBCT scan

Each block was placed on the CBCT machine scan holder after labeling the holder with four marks to standardize the blocks position labelled with the letter "A" representing the front position. Each block was scanned separately using a CBCT machine on Endo mode with these exposure parameters (Field of view 5*5 cm, 10 mA,

90 KvP and 85µm voxel size). Images were reconstructed and imported to On-demand (3D software Cybermed) **(Figure 2)**.

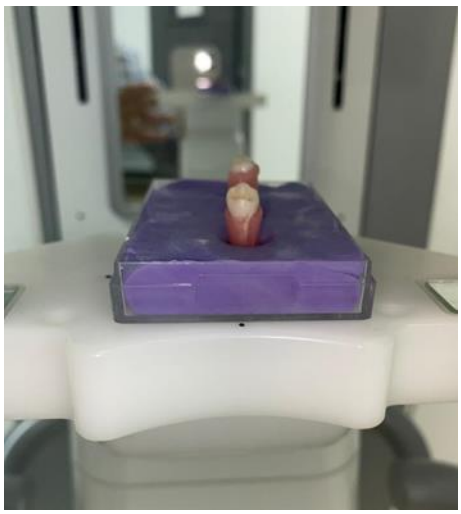

Figure (2): Block ready for CBCT.

Dentin thickness was measured on axial CBCT sections at four different surfaces (buccal, lingual, mesial, and distal) at levels 3, 5, 7 mm from the apex. Measurements were taken in straight lines from the most inner part of the indentation marks to the internal root surface. This was done four times for each surface, and average measurements were calculated at each level.

In groups A&B: Traditional designs were prepared following the conventional guidelines in order to obtain a straight-line access.[9] The preparation was made oval in shape, corresponding to pulp chamber shape. In groups C&D: conservative access was done one mm buccal to the central fossa with minimal extension enough to detect canal orifices, to preserve pericervical dentin, part of the chamber roof and lingual shelf with no subsequent removal of tooth structure, obtaining slightly oval-shaped minimal cavities.[10] **(Figures 3, 4)**.

Figure (3): Traditional access.

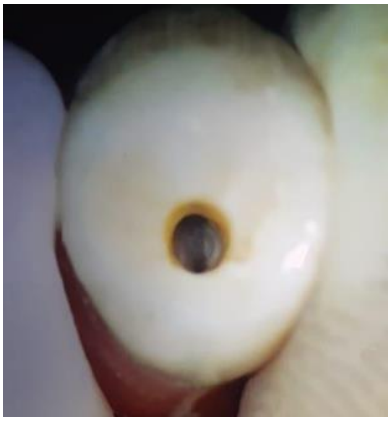

Figure (4): Conservative access.

Root canal preparation

In CMA traditional and conservative groups:- Glide path was confirmed using #10 and #15 k hand files. Canals were prepared in a sequence of the coronal file, median file, apical 1 file, apical 2 files and finally median file in brushing motion.

In M3 Pro gold traditional and conservative groups:-Glide path was also

done, Then Open file was used followed by, Path file then shaping file in pecking motion. At last shaping file was used in brushing motion.

Irrigation of the root canals was done with 10 ml of 2.5% NaOCl intermittently with a 27-gauge side vented needle and syringe.

Postoperative CBCT scanning

Samples were re-scanned using the same preoperative standardized block positions and exposure parameters. The amount of removed dentin thickness was calculated by subtracting the postoperative readings from the preoperative **(Figure 5)**.

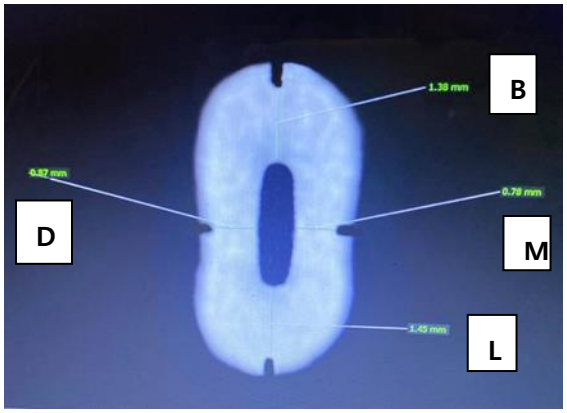

Figure (5): axial cuts presenting the postoperative B, L, M and D dentin thickness.

Specimen preparation for fracture resistance test

All roots were individually mounted vertically in blocks prepared with acrylic resin to a depth of 1 mm apical to the cement-enamel junction. Periodontal ligament simulation was done with Teflon. Blocks were mounted on the universal testing machine with a loading fixture with a spherical tip diameter of 4.8 mm and aligned with the center of root canal opening for each root **(Figure 6)**.

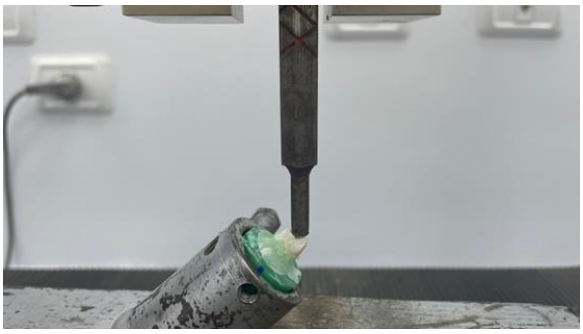

Figure (6): loading force applied at 30 degrees inclination angle.

A loading force was applied until root fracture occurred using a 30-inclination angle.

Force was recorded in Newton by using the following formula:

MPa =Maximum load in Newtons (N)

$\pi / 4 \times (4.8mm)2$

- $\pi = 3.14$ (constant value)
- Area of cross-section of plunger =4.8mm.

Statistical Analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data were presented as median, range, mean, and standard deviation (SD)

values. Mann-Whitney U test was used to compare between two access types, and the two systems. Friedman's test was used to compare between remaining dentin thickness at coronal, middle, and apical root levels. Spearman's correlation coefficient was used to determine the correlation between remaining dentin thickness and fracture resistance. The significance level was set at $P \leq 0.05$.

RESULTS

A) Dentin thickness

- Non-significant difference was observed between traditional and conservative access cavity dentin thickness removed at all levels after being prepared with CMA and M3 Pro Gold. **(Table 1).**

- Comparing CMA and M3 Pro gold systems removed dentin thickness at all levels after teeth being accessed traditionally; non-significant difference was observed. For conservative access, there was a non-significant difference at coronal and middle levels. However, at the apical level, CMA showed significantly lower mean value than M3 Pro Gold with P value 0.031. **(Table 2).**

- No significant difference between removed dentin thickness at different root levels after being prepared with M3 pro gold system in traditional and conservative access cavities designs. For CMA traditional and conservative groups, there was no statistically significant difference too. **(Table 3).**

B)Fracture resistance

- Non-significant difference was observed between traditional and conservative access cavity fracture resistance after being prepared with CMA and after using M3 Pro gold systems. **(Table 4).**

Table (2): Descriptive statistics and results of Mann-Whitney U test for comparison between removed dentin thickness (mm) of the two systems.

Access type	Root level	CMA (n = 5)		M3 Pro Gold (n = 5)		*P*-value	*Effect size (d)*
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Traditional	Coronal	0.2 (0.1-0.4)	0.22 (0.13)	0.3(0.2-0.4)	0.32 (0.08)	0.192	0.863
	Middle	0.2 (0.1-0.3)	0.2 (0.1)	0.4(0.2-0.4)	0.34 (0.09)	0.052	1.479
	Apical	0.1 (0.1-0.2)	0.14 (0.05)	0.2(0.1-0.4)	0.26 (0.13)	0.118	1.043
CAC	Coronal	0.2 (0.1-0.3)	0.2 (0.07)	0.2(0.1-0.4)	0.24 (0.11)	0.575	0.335
	Middle	0.2 (0.1-0.3)	0.22 (0.08)	0.3(0.1-0.4)	0.28 (0.13)	0.389	0.548
	Apical	0.2 (0.1-0.2)	0.16 (0.05)	0.3(0.2-0.3)	0.26 (0.05)	0.031	1.612

**: Significant at P ≤ 0.05.*

Table (3): Descriptive statistics and results of Friedman's test for comparison between removed dentin thickness (mm) at different root levels within each group.

Access type	Root level	CMA (n = 5)		M3 Pro Gold (n = 5)	
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)
Traditional	Coronal	0.2 (0.1-0.4)	0.22 (0.13)	0.3 (0.2-0.4)	0.32 (0.08)
	Middle	0.2 (0.1-0.3)	0.2 (0.1)	0.4 (0.2-0.4)	0.34 (0.09)
	Apical	0.1 (0.1-0.2)	0.14 (0.05)	0.2 (0.1-0.4)	0.26 (0.13)
P-value		0.247		0.646	
Effect size (w)		0.28		0.088	
Conservative	Coronal	0.2 (0.1-0.3)	0.2 (0.07)	0.2 (0.1-0.4)	0.24 (0.11)
	Middle	0.2 (0.1-0.3)	0.22 (0.08)	0.3 (0.1-0.4)	0.28 (0.13)
	Apical	0.2 (0.1-0.2)	0.16 (0.05)	0.3 (0.2-0.3)	0.26 (0.05)
P-value		0.368		0.819	
Effect size (w)		0.2		0.04	

**: Significant at P ≤ 0.05.*

Table (4): Descriptive statistics and results of Mann-Whitney U test for comparison between fracture resistance (N) of the two access types.

Access type	CMA		M3 Pro Gold	
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)
Traditional	93.8 (36.5-139)	90.3 (40.8)	130.6 (62.3-185.9)	127.4 (60)
Conservative	101.3 (65.8-178.1)	123.6 (50.9)	99.4 (50.5-103.7)	83.6 (24.5)
P-value	0.251		0.462	
Effect size (*d*)	0.78		0.78	

**: Significant at P ≤ 0.05.*

- Comparing fracture resistance for traditional access using CMA and M3 pro gold, a non-significant difference was observed. For conservative access using CMA and M3 pro gold, a non - significant difference was observed too. **(Table 5).**

Table (5): Descriptive statistics and results of Mann-Whitney U test for comparison between fracture resistance (N) of the two systems 123.6 (50.9) and 83.6 (24.5).

System	Traditional		Conservative	
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)
CMA	93.8 (36.5-139)	90.3 (40.8)	101.3 (65.8-178.1)	123.6 (50.9)
M3 Pro Gold	130.6(62.3185.9)	127.4 (60)	99.4 (50.5-103.7)	83.6 (24.5)
P-value	0.462		0.251	
Effect size (*d*)	0.78		0.78	

**: Significant at P ≤ 0.05.*

DISCUSSION

Successful root canal treatment comprises three main steps; access cavity followed by biomechanical preparation and 3D obturation with biocompatible material. The traditional endodontic access cavity (TEC) design focuses on the inclusion of all pulp horns, and removal of the roof of the pulp chamber in order to ensure complete debridement of the root canal system. However, excessive removal of tooth structure increases cuspal deflection that negatively reduces mechanical and biological tooth responses and tooth deformability. That's why there is a need for less invasive technique in order to prevent loss of endodonitcally treated teeth.[11–13]

Inspired by the minimally invasive concept, conservative endodontic access cavity (CAC) design is a means of minimizing tooth structure ejection by preserving some of the chamber roof and peri-cervical dentin. The cavity design affected the chemo-mechanical preparation and the file system used.[14]

Cleaning and shaping of root canal space is one of the most important and fundamental aspects of endodontic therapy. Conventionally, endodontic instrumentation was done by stainless steel hand files, which had their own problems, such as stiffness and taper. To overcome these limitations, Nickel Titanium (NiTi) instruments were introduced[13,14]

Advancements in rotary nickel titanium instruments have led to new concepts and techniques of canal preparation. Most of the new systems incorporate instruments with a taper greater than the ISO standard 0.02 taper design. Now nickel titanium instruments are available with tapers ranging from 0.04 to 0.12, allowing varying levels of removed dentin volume.[15]

The increase in root canal taper makes more space for the irrigation fluids making the cleaning process more efficient and facilitating obturation. However, larger taper correlates to a decrease in the fracture resistance due to excessive flaring of the canals. So, preservation of residual dentin is an essential requirement for the longevity of an endodontically treated tooth.[16]

In the current study, premolars were the selected samples since cusp fractures commonly occur in premolars due to the undesirable ratio of the crown to root and exposure to shear forces.[17]

The two rotary systems were selected based on having the same cross section (convex triangle), non-cutting tips but variable taper to compare the effect of different root canal tapers on fracture strength of endodontic treated teeth and remaining cervical dentin thickness. M3pro

gold is composed of an orifice opener (8%), path file (2%), shaping file (6%), shaping file(4%), and finishing file(6%), CMA system is composed of a coronal file (10%), median file (6%), apical file one (4%) and apical file two (6%), all files of both systems have non cutting tips and used in rotational motion.

Embedding of the used teeth in a thin layer of Teflon was applied to simulate the periodontal ligament in the clinical situation.

Radiographic examinations as conventional and digital radiographic techniques were adopted for teeth visualization, but present a 2D image of a 3D object. To visualize the 3D object more accurately, CBCT has emerged as a powerful tool for the evaluation of root canal morphology. It can render cross-sectional and three-dimensional images of teeth and jaws that are highly accurate and quantifiable.[18,19]

CBCT scanning was used in this study to compare dentin thickness pre-instrumentation and post-instrumentation with CMA and M3 pro gold system rotary systems. This allows visualization of the root canal in three planes (axial, coronal, and sagittal) that provide the most accurate measurements of the root .Teeth samples were embedded in wax blocks and they were coded with teeth arrangement for standardization of teeth imaging before and after instrumentation. Four markers were used as labels on the CBCT scan holder to standardize position of the block. Endo mode was used for teeth scanning. The amount of removed dentin thickness was calculated by subtracting the postoperative readings from the preoperative one.[8]

Fracture resistance of teeth can be measured by different methods, one of the most common way is using Universal Testing machine which was in accordance with various studies.[20] Since teeth are most vulnerable to fracture when eccentric forces are applied, reaching the failure point at lower loads compared to other studies with axial fracture loads that is why 30-degree inclination angle is more useful.[21]

The statistical analysis showed no significant difference between traditional and conservative access cavity designs. This may be due to using premolasrs samples which already have small occlusal tables; therefore, the difference between traditional and conservative access cavity designs will not strongly affect the remaining dentin thickness. Also, there was no significant difference found between CMA and M3 Pro Gold after teeth being accessed traditionally and conservatively. This was confirmed by Tomer who compared the remaining dentin thickness of root canals with different rotary

systems and declared that the cutting efficiency was mainly affected by cross section design more than the taper.[22]

These results were confirmed by Silva et al.[23] who tested the influence of traditional and conservative access cavity preparations on the remaining dentine thickness in extracted mandibular molars prepared with reciprocating instruments using microcomputed tomography and concluded that there was no significant difference due to sample selection which was based on morphometric parameters of the root canal system (configuration, length, volume, and geometry) to ensure comparability of the groups.

Unfortunately, these results were opposed by Makti et al.[24] who compared the remaining dentin thickness of traditional and conservative access in molars using CBCT and observed significant difference between groups. This may be due to use of molars which have extensive occlusal table that can be highly influenced by the difference in access design and use of self-adjusting file in the conservative group which removes dentin by scrubbing and scraping rather than cutting of dentin chips preserving more radicular dentin.

In this study, no significant difference was observed between conventional and conservative access cavity designs, also between CMA and M3 Pro gold rotary systems, but what affected mainly the amount of dentin removed was the comparison between the systems along the different levels after teeth being accessed conservatively. Non-significant difference at the coronal and middle levels; however, at the apical level, CMA showed statistically significantly lower value of remaining dentin thickness than M3 Pro Gold. This is explained through configuration of premolars anatomy where; the shape was oval at the coronal third, round or oval at the middle third, and round in the apical third sections. This configuration caused less contact of rotary files to the tooth structure and more untouched areas in the coronal part, while in the apical round part, any change in the instrument apical taper affects the dentin thickness apically. These results are comparable to those reported by Ingle and Bakland.[25] Moreover, multiple different results tested the amount of dentin thickness along the 3 levels and unfortunately declared a significance difference between the used systems. This may be attributed to the difference in geometrical design of the systems.[26,27]

Fracture resistance presented no significant difference between two access cavity designs: traditional and conservative, whether with CMA or M3 Pro Gold

systems, respectively. Also, no significant difference was observed between the two systems (CMA, M3Pro gold), whether with traditional or conservative access cavities. These results were confirmed by Sabeti et al.[9] and Ozyurek et al.[28] who stated that there was no significant difference between both cavity designs. This may be due to the use of premolars with smaller occlusal table, so the contracted design did not improve fracture resistance. Again using nickel titanium instruments with close geometrical designs did not significantly affect the amount of dentin removed.

Unfortunately, these results were opposed by Krishan et al.[29] and Ganesh et al.[30] who justified using conservative access as an alternative to traditional access since it increased fracture resistance compared with those accessed traditionally. This may be due to using hand files in comparison with rotary files where hand files that had 2% taper when compared with a variable taper of rotary files caused the removal of less amount of dentin affecting teeth fracture resistance, using teeth with curved roots abnormal canal anatomy which influences the pattern of fracture and finally using compression test which can affect the obtained results since it did not faithfully reproduce the clinical situation.

Conservative concept has been adopted in endodontics recently. However, conservative endodontic access cavity design cannot represent a valid alternative to traditional endodontic access cavity, since it neither increases fracture resistance of endodontically treated teeth nor influences their biomechanical behavior.

CONCLUSIONS

Within the limitations of this in-vitro study, the following points were concluded:

1. Conservative access cavity design failed to preserve teeth structure and intensify the fracture resistance of mandibular premolars.
2. Minimal invasive root canal taper stands short of enhancing the fracture resistance of root canal treated mandibular premolars.
3. Cervical taper within 8% and 10% presented a similar effect on cervical dentin thickness in mandibular premolars.

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REFERENCES

1. Kapetanaki I, Dimopoulos F, Gogos C. Traditional and minimally invasive access cavities in endodontics: a literature review. Restor Dent Endod. 2021; 46(3):

1–9.

2. Jiang Q, Huang Y, Tu XR, Li Z, He Y, Yang X. Biomechanical Properties of First Maxillary Molars with Different Endodontic Cavities: A Finite Element Analysis. J Endod. 2018;44(8):1283–8.
3. Saeed M, Al-Obadi M, Salim A, Alsawaf AY, Hadi K. Impact of access cavity design on fracture resistance of endodontically treated molars: A systematic review. Clin Cosmet Investig Dent. 2021;13:1–10.
4. Chlup Z, Žižka R, Kania J, Přibyl M. Fracture behaviour of teeth with conventional and mini-invasive access cavity designs. J Eur Ceram Soc. 2017;37(14):4423–9.
5. Ballester B, Giraud T, Ahmed HMA, Nabhan MS, Bukiet F, Guivarc'h M. Current strategies for conservative endodontic access cavity preparation techniques systematic review, meta-analysis, and decision-making protocol. Clin Oral Investig. 2021;25(11):6027–44.
6. Acharya N ,Hasan MD , Kafle D, Chakradhar A and Saito T. Effect of Hand and Rotary Instruments on the Fracture Resistance of Teeth: An In Vitro Study. Aust Endod J. 2021;47(3):499–505.
7. Deopujari J, Singh H, Pathak I, Shyamal R, Antony SM, Singh S. Evaluation of Microcracks formed During Root Canal Preparation by Different File Systems Using Micro-computed Tomography : An In Vitro Study. J Contemp Dent parctice. 2022;23(1):74–8.
8. Mittal S, Sharma D, Kumar A, Kamal S, Gupta K, Pathania V. Cone Beam Computed Tomographic Evaluation of Effect of Different Taper and Technique of Biomechanical Preparation on Root Dentin Thickness : An in Vitro Study. J Pediatr Dent. 2021;7(3):136–45.
9. Sabeti M, Kazem M, Dianat O, Bahrol-olumi N, Beglou A, Rahimipour K and Dehnavi F . Impact of Access Cavity Design and Root Canal Taper on Fracture Resistance of Endodontically Treated Teeth: An Ex Vivo Investigation. J Endod. 2018;44(9):1402–6.
10. Hegde DV, Singh DN, Ansari DA. Comparative evaluation of the fracture resistance of endodontically treated teeth with different access designs. Int J Appl Dent Sci. 2021;7(3):258–64.
11. Zang Y, Liu Y, She Y, Liang Y, Xu F, Fang C. The Effect of Endodontic Access Cavities on Fracture Resistance of First Maxillary Molar Using the Extended Finite Element Method. J Endod. 2019;45(3):316–21.
12. Freitas GR, Ribeiro TM, Vilella FSG, de Melo TAF. Influence of endodontic

cavity access on curved root canal preparation with ProDesign Logic rotary instruments. Clin Oral Investig. 2021;25(2):469–75.

13. Ramanathan S, Solete P. Cone-beam Computed Tomography Evaluation of Root Canal Preparation using Various Rotary Instruments: An in vitro Study. J Contemp Dent Pract. 2015;16(11):869–72.
14. Kumar T, Mittal S, Keshav V, Kaur R and Maakhni E. An, A comparative evaluation of remaining dentin thickness following biomechanical preparation of teeth using differentrotary file systems: Vitro, In Study. JConserv dent. 2022;21(4):373–7
15. Suneetha MG, Moiz AA, Sharief H, Yedla K , Baig MM and Abu Al Qomsan MAS. Residual root dentin thickness for three different rotary systems: A comparative cone beam computed tomography in vitro study. J indian Soc Pedod Prev Dent. 2020;38(1):48–55.
16. Maqbool M, Noorani TY, Asif JA, Makandar SD, Jamayet N Bin. Controversies in endodontic access cavity design: A literature review. Dent Update. 2020;47(9):747–54.
17. Al-Ibraheemi ZA, Abdullah HA, Jawad NA, Haider J. Assessing Fracture Resistance of Restored Premolars with Novel Composite Materials: An in Vitro Study. Int J Dent. 2021;10:1-10.
18. Chen B, Martin G, Arce G, Boetto AC, Braschi SM, Marchegiani S. Root dentine thickness in C-shaped lower second molars after instrumentation : A CBCT and micro-CT study. Aust Endod J 2021;47:122–129.
19. Ammar SA, Sabet NE and Bastway HA . Accuracy of CBCT, Digital and conventional radiography in evaluating the shaping performance of a novel NiTi rotary system (An in vitro study. Egypt Dent J. 2020;66(4):2751–61.
20. Corsentino G, Pedullà E, Castelli L, Liguori M, Spicciarelli V, Martignoni M, Ferrari M and Grandini S. Influence of Access Cavity Preparation and Remaining Tooth Substance on Fracture Strength of Endodontically Treated Teeth. J Endod. 2018;44(9):1416–21
21. Plotino G, Grande NM, Isufi A, Ioppolo P, Pedullà E, Bedini R, Gambarini G and Testarelli L. Fracture Strength of Endodontically Treated Teeth with Different Access Cavity Designs. J Endod. 2017;43(6):995–1000.
22. Tomer AK, Gupta R, Behera A. An in-vitro evaluation of remaining dentine thickness through CBCT using different file. Int J Appl Dent Sci. 2018;4(3):9–13.
23. Silva EJNL, Rover G, Belladonna FG,

De-Deus G, Teixeira C. Impact of contracted endodontic cavities on fracture resistance of endodontically treated teeth: a systematic review of in vitro studies. Clin Oral Investig. 2017;22(1):109–18.

24. Makati D, Shah NC, Brave D, Rathore VPS. Evaluation of remaining dentin thickness and fracture resistance of conventional and conservative access andbiomechanical preparation in molars using cone-beam computed tomography: An in vitro study. J Conserv Dent. 2018;21(3):324–7.
25. Khedmat S, Assadian H and Saravani AA. Root Canal Morphology of the Mandibular First Premolars in an Iranian Population Using Cross-sections and Radiography. J Endod. 2010;36(2):214–7.
26. Mahran AH, AboEl-Fotouh MM. Comparison of Effects of ProTaper, HeroShaper, and Gates Glidden Burs on Cervical Dentin Thickness and Root Canal Volume by Using Multislice Computed Tomography. J Endod. 8;34(10):1219–22.
27. Nagi SE, Khan FR, Rahman M. Remaining dentine thickness of root canals prepared with K-3 and ProTaper rotary systems. J of Pakistan Med Ass. 2017;67(12):1814–7.
28. Özyürek T, Ülker Ö, Demiryürek EÖ. The Effects of Endodontic Access Cavity Preparation Design on the Fracture Strength of Endodontically Treated Teeth: Traditional Versus Conservative Preparation. J Endod. 2018;44(5):800–5.
29. Krishan R, Paqué F, Ossareh A, Kishen A. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. J Endod. 2014;40(8):1160–6.
30. Ganesh A, Venkateshbabu N, John A, Deenadhayalan G, Kandaswamy D. A comparative assessment of fracture resistance of endodontically treated and re-treated teeth: An in vitro study. J Conserv Dent. 2014;17(1):61–4.