EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 1965:1975, April, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 05-11-2023 • Accept Date : 26-01-2024 • Available online: 20-04-2024 • DOI : 10.21608/EDJ.2024.246355.2768

INFLUENCE OF CONTRACTED ACCESS CAVITY ON CANALS SHAPING GEOMETRY USING DIFFERENT DESIGNS NITI ROTARIES- A CBCT STUDY

Manal Mohamed Abdelbaky*, Rehab Ali Farag*
and Maram Ezzat Khallaf**

ABSTRACT

Aim: To investigate the influence of Contracted Access Cavity (CEC) design and two dissimilar final preparation tapers-using ProtaperNext (PTN) and OneShape (OS) on the canals shaping geometry as compared to the Traditional Access Cavity (TEC) using CBCT.

Methodology: Sixty mandibular molars with two separate roots were randomly classified into 4 groups (n=15) were scanned with CBCT, namely: TEC/PTN, TEC/OS, CEC/PTN, and CEC/OS. Instrumentations in each group were done following the manufacturer protocol for each instrument type. A second scan was made after canals instrumentations. Three root levels were selected namely 3,6, and 9mm from the roots apices. Results were statistically analyzed using repeated measure ANOVA followed by paired sample t-test and One-way ANOVA followed by Tukey post hoc test.

Results: All test groups showed significant canals transportation to varying degrees ($p<0.05$). At 3mm from the apex, TEC/ PT showed statistically significant least transportation, while largest transportation was found in CEC/PT while CEC/OS and TEC/OS values were in between. Comparing the values of transportation using either PTN or OS showed a statistically significant higher transportation values for (CEC) as compared to (TEC) irrespective of the rotary instrumentation used; where ($p<0.001$). On the other hand for the centering ability, no statistically significant difference between (CEC) and (TEC) groups where found ($p=0.060$).

Conclusion: Significantly higher transportation values was found for (CEC) as compared to (TEC) irrespective of the rotary instrumentation used. For the centering ability, no statistically significant difference between (CEC) and (TEC) groups where found using either PTN or OS.

KEYWORDS Centering ability, Transportation, ProTaperNext, OneShape, CBCT

* Lecturer of Endodontics, Conservative Surgery Department, Faculty of Oral and Dental Surgery, Must University, Cairo, Egypt
** Professor of Endodontics, Restorative and Dental Materials Department, National Research Centre, Cairo, Egypt

INTRODUCTION

Non-surgical endodontic treatment of the root canal space typically involves accessing the canal through the coronal access cavity. This cavity should be strategically positioned and oriented towards the canal system with a planned, target to reach the apical part of the canal unobstructed. The goal is to completely remove the pulp chamber roof so that; all canals can be visualized and accessed[1]. This allows for thorough cleaning and shaping of the root canal systems[2].

In recent years, the conservative approach to restorative dentistry moving away from the old concept of extension for prevention to minimally invasive approach[3]. This change has been supported by advancements in adhesive restorative materials and techniques. Similarly, in endodontics, conservative approach to the root canal system is crucial for preserving the longevity of the tooth following endodontic treatment.

In surgical endodontics, the use microscopes revolutionized micro-endodonticsby allowing for precise use of mini-instruments, cavities. This allowed for maximizing benefits of tooth and tissue preservation and quality of life improvement[4-6]. Recently,there have been proposals for conservativeaccess cavity designs, each with a different abbreviation- aimedat preserving the criticalpericervical dentin[7-9].These include Conservative Endodontic Cavities (CEC), Ultraconservative Access Cavities (Truss and Ninja), and the Computer-Assisted Access Cavity (CAAC) [10-12].

Research surveys have revealed a wealth of experimental investigation on the contracted access geometry currently being presented[13,14]. This includes studies on the digital designs, canal debridement and instrumentation effectiveness through contracted access [1,5,7,15,16,], as well as instrument's fracture strength [13].

Most of these studies compared multiple conservative access cavities designs at a time.[17] This might potentially leads to conflicting and negative conclusions about conservative cavity concepts[7,14,16]. However, the mid-way approach exemplified by the conservative access (CECs) where a significant segment of the pulp chamber roof and peri-cervical dentin are preserved needs to be further searched.

The fracture resistance of endodontically treated teeth following either conventional access (TEC) or contracted access approach has been previously studied; with consistently favorable results for the contracted access[18,19]. Additionally, some studies, have demonstrated that teeth prepared through the TEC design exhibited significantly lower resistance to fracture compared to those prepared through the CEC design. However, a recent systematic review found that, access designs had no significant effect on tooth fracture resistance [20].

The value of different designs of contracted accesses in shaping efficiency has been the subject of numerous focused studies; using Micro-Computed Tomography(MCT);or Cone Beam Computed Tomography (CBCT)[16,21-23] and/or different NiTi instruments and instrumentation techniques[22,23]. However, most of these studies have been found to be inconclusive and further research is recommended to build the evidence. This statement is especially applicable to the distal canals of mandibular molars which have been reported to have eccentric preparation related to their anatomical characteristics [14,15,22].

Statement of the Problem

The current literature has related CEC to the risk of compromised canal instrumentation particularly in the distal canals of mandibular molars. However,there is insufficient information in the literature regarding the effect of using NiTirotary files with different designs on the shaping parameters of the distal root canals of mandibular molars.

AIM OF STUDY

The aim of this study was to compare between CEC and TEC designs after using two dissimilar NiTi files-namely, Protaper Next (PTN) and OneShape (OS) regarding the shaping parameters of the distal root canals of mandibular first molars using CBCT.

Null Hypotheses

1. There is no significant difference between the CEC and TEC designs concerning canal's transportation or centric ability
2. The rotary instrument designs used have no effect on the canal's transportation or centric ability

Methodology

Sample Collection and Calculation

Freshly extracted mandibular first molars were selected for the study. Teeth were gathered from the teeth store bank at the faculty of Oral and Dental Surgery, MUST University. Local ethical committee approval was gained. Sample size calculation was found to be 15 per group as calculated with G*Power 3.1.4 (Kiel University, Kiel, Germany) to set the study power at 80% (a large effect size equal to 1 was considered for the sample size calculated)[16]. Accordingly; sixty freshly extracted human permanent lower first and second molars will be selected to the study.

Inclusion criteria and exclusion criteria:

Sixty mandibular first molars were selected from the pool of extracted teeth. Selected teeth had fully formed apices, non carious, no fused or severely curved roots, no cracks or fractures or external root resorption. Radiographs showed no internal resorption, canals calcifications, or previous RCT.Teethwere selected to possess a distal root with a single canal of type I [24]. Canal curvature within 5°-10°[25].

Teeth Specimen's Pre-Test Preparation and Storage

Cleaned teeth samples were immersed in a 0.01% solution of sodium hypochlorite (NaOCl) for 24 hours; after which they were stored in saline solution until the experiment time. The same storage was followed during different phases of intervention to prevent specimens' dehydration.

Pre-instrumentation CBCT:

Teeth specimens were inserted vertically in two specially constructed horse-shoe molds that simulate a human jaw. Images were acquired using the CBCT (i-CAT) imaging system (Imaging sciences international). The i-CAT is equipped with an amorphous Silicon Flat Panel and a single 360 degrees scan collects the projection data for reconstruction. The samples were exposed to an X-ray field size of 16 cm diameter x 4 cm height. The scanning time was specified as 26.9 seconds. The operating parameters were 120 kVp, and 5 mA with slice thickness of 0.125 mm. Virtual three dimensional root canal models were reconstructed. Image stacks were processed for volume registration, matching and cutting plane selection using Data Viewer software.

Specimens grouping and allocation:

Teeth specimens were randomly divided into four groups (n=15) and allocated according to the access cavity designs and instruments used as follows: Group 1: CEC, distal roots for instrumentation by PTN (Dentsply Sirona, Tulsa, OK). Group 2:TEC, distal roots to be instrumented by PTN. Group 3: CEC, distal roots to be instrumented by OS(25/.06) (Micro Mega, Besancon, France) and Group 4: TEC, distal roots to be instrumented by OS.

Access cavities preparation and instrumentation

TECs were prepared in teeth of groups 2 and 4 while CECs were made in teeth of groups 1 and 3. The two designs accesses were made following the reported description. All accesses were made using high speed round carbide bursfor initial penetration through the central fossauntil exposure then tapered diamond burs were used to make the extensions according to each group access design. Copious water spray accompanied all access preparations.

For the TEC groups; traditional access cavities were made by removal of all pulp chamber roof guided by its extensions as previously described [26]**.**

For the CEC groups;contracted cavitieswere accessed at the central fossa and extended only asrequired to access canal orifices while preserving the rest of pulp chamber roof and peri-cervical dentin as previously demonstrated[14,15,21,27].

All accesses were made by a single endodontic specialist, well trained, not blinded to the access design but blinded to the study aims.

Canal system was then irrigated, ready for the shaping steps.

Distal root canals were then shaped using the specified instrument type and in accordance with the manufacturers' directions. AVDWSilver motor (VDW, Munich, Germany)was used for all instrumentations. Throughout the instrumentation, canals were irrigated with 1 ml of sodium hypochlorite 2.5% before and after each rotary file use. This totaled 7ml of sodium hypochlorite volume irrigation for each tooth's distal canal. Cleaning of the files was repeatedly done using sterile gauzes.Preparation details were as follows:

For PTN: after glide path confirmation, in the presence of NaOCl, X1(17/04) file was used in a brushing motion to the apex. This was followed by X2(25/06), and X3(30/07). After each file recapitulation with a hand file and irrigation were made as per manufacturer directions. Each file was used in preparation of three canals before discarding and replacement by a new one.

For OS: glide path confirmation and canal orifice enlargement was made using SX (DentsplyMaillefer, Ballaigues, Switzerland), OS single instrument was used in a continuous rotation in a crown down preparation techniquedown to the apex-as per manufacturer recommendations.All canals preparation were preceded and followed by NaOCl irrigation. Each file was used in preparation of three canals before discarding and replacement by a new one as per manufacturer recommendations [28]Final irrigation was made for all prepared canals groups, canals dried with paper points ready for the second CBCT examination.

Post-instrumentation CBCT:

CBCT Imagesfor the teeth specimens were made after shaping for matching. CBCT scans were managed to enable pre- and postoperative evaluation for each group (Figure 1).

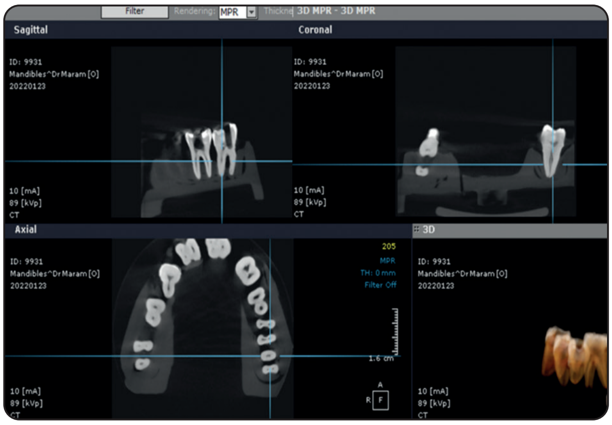

Fig. (1) Sample composite CBCT Photograph showing Sagittal, Coronal, Axial views of teeth specimens with TEC (upper left tooth) and CEC (upper right tooth) in the sagittal plan

All pre-specified parameters were calculated for the teeth specimens using 3D Slicer 4.6.2 software.

Calculated study parameters for the experimented canals of each group were done according to Gambill et al (1996)[14,22]equations as follows:

1. Degree of canals' Transportation; calculated by the software(Fiji 1.46r software (ImageJ, Madison, WI) such that,(M1 - M2) - (D1 -D2) equals

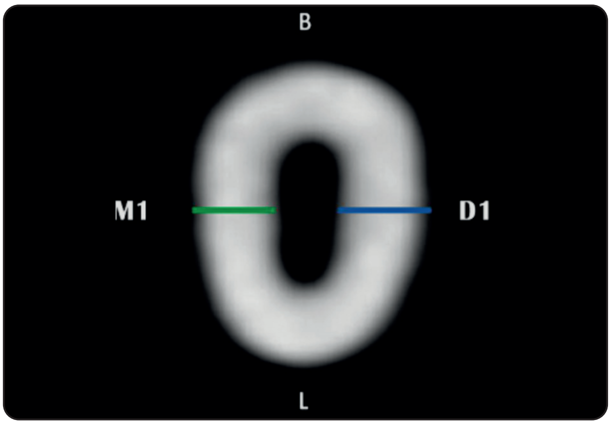

Fig. (2) CBCT Photograph showing representative cross section of a distal root and canal specimen showing calculated parameters before instrumentation.

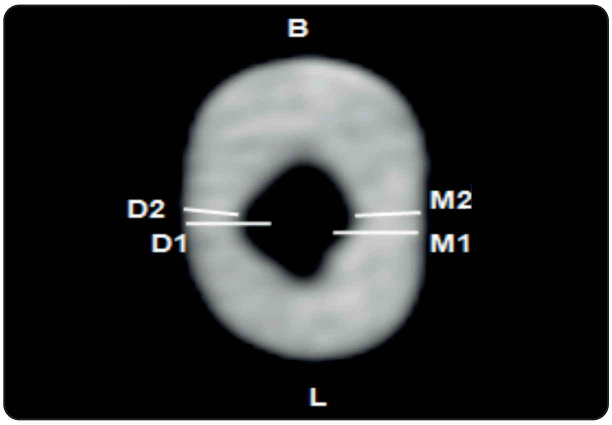

Fig. (3) CBCT Photograph showing representative cross section of a distal root and canal specimen, calculated parameters after instrumentation, transportation, and centroid change.

degree of transportation. M1 represented the width of the dentin cross section from the periphery to the canal mesially before preparation. D1 represented the width of the dentin cross section from the periphery to the canal distally before preparation. M2 and D2 are the corresponding widths after preparation.

2. Canals' Centering ability; calculated using same dentin width measurements but with the equation M1 - M2\ D1 - D2 or D1 - D2\ M1 - M2

Statistical analysis:

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests which showed parametric –normal- distribution. Repeated measure ANOVA followed by paired sample t-testswere used to compare more than two groups in related samples, while One-way ANOVA followed by Tukey post hoc test were used for non-related samples. The significance level was set at P ≤ 0.05. Statistical analysis was performed using IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Canal Transportation:

A. Inter-group: Results are presented in table 1

CEC Protaper:

There was no statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.716).

TEC Protaper:

There was a statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.001).

A statistically significant difference was found between (3mm) and each of (6mm) and (9mm) groups where (p=0.013) and (p=0.005).

No statistically significant difference was found between (6mm) and (9mm) groups where (p=0.120).

CEC OneShape:

There was a statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.005).

A statistically significant difference was found between (3mm) and each of (6mm) and (9mm) groups where (*p*=0.015) and (p=0.007).

No statistically significant difference was found between (6mm) and (9mm) groups where (*p*=0.722).

TEC OneShape:

There was no statistically significant difference between (3mm), (6mm) and (9mm) groups where (*p*=0.289).

B. Intragroup

Degree of Canals' Transportation:

Results are presented in table 1.and figure 4

At 3 mm from the apex, the maximum canal transportation was calculated for CEC/PTN group, followed by TEC/OS, CEC /OS, and TEC/PTN (least transportation) in descending order (Fig.4). The differences were statistically significant (*p*= 0.001).

At 6mm from the apex, the maximum canal transportation was calculated for CEC/OS group, followed by CEC/PTN, TEC/OS, and TEC/PTN(least transportation) in descending order. The differences were statistically significant (*p*= 0.002).

At 9mm from the apex, the maximum canal transportation was calculated for CEC/OS group, followed by CEC/PTN, TEC/PTN, and TEC/OS (least transportation) in descending order. The differences were statistically significant (*p*= 0.002).

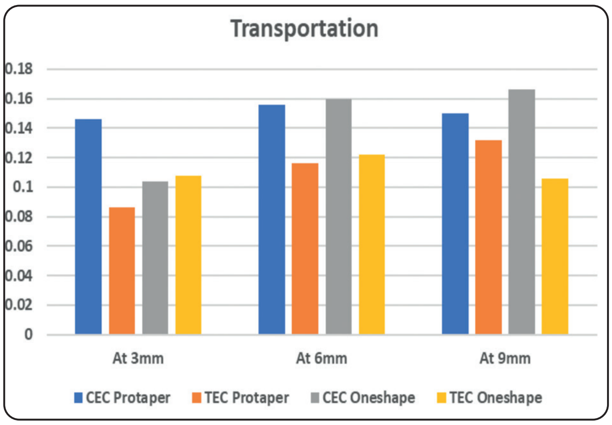

Fig. (4): Bar chart showing the differences in canals' transportation in three tested cross sectional levels between the two experimented access designs concerning degree of canals' transportation

Centering ability:

Inter-group: Results are presented in table 2

CEC Protaper:

There was a statistically significant difference between (3mm), (6mm) and (9mm) groups where (*p*=0.020).

TABLE (1) Mean and Standard Deviation (SD)- values of Transportation of different groups.

Variables	Transportation						p-value
	At 3mm		At 6mm		At 9mm		
	Mean	SD	Mean	SD	Mean	SD	
CEC/PTN	0.146	0.024	0.156	0.027	0.150	0.016	0.716ns
TEC/PTN	0.086	0.015	0.116	0.009	0.132	0.016	0.001*
CEC/ OS	0.104	0.018	0.160	0.020	0.166	0.028	0.005*
TEC/ OS	0.108	0.013	0.122	0.011	0.106	0.019	0.289ns
p-value	0.001*		0.002*		0.002*		

.; significant (p<0.05) ns; non-significant (p>0.05)*

A statistically significant difference was found between (3mm) and each of (6mm) and (9mm) groups where (p=0.026) and (p=0.029).

No statistically significant difference was found between (6mm) and (9mm) groups where (p=0.141).

TEC Protaper:

There was a statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.044).

No statistically significant difference was found between (6mm) and each of (3mm) and (9mm) groups where (p=0.059) and (p=0.121).

A statistically significant difference was found between (3mm) and (9mm) groups where (p=0.039).

CEC OneShape:

There was no statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.294).

TEC OneShape:

There was a statistically significant difference between (3mm), (6mm) and (9mm) groups where (p=0.039).

No statistically significant difference was found between (3mm) and each of (6mm) and (9mm) groups where (p=0.347) and (p=0.054).

A statistically significant difference was found between (6mm) and (9mm) groups where (p=0.037).

Intragroup

Results are presented in table 2 and figure 5

At 3 mm from the apex, the two tested cavity designs as well as the two rotary instrument designs showed statistically insignificant differences in the centering ability (p0.276). However, the TEC/OS was the mostcentered in the canal (0.66). This was followed by CEC/PTN, TEC/PTN, and CEC/OS in descending order (Fig.5).

At 6 mm from the apex, the two tested cavity designs and the two rotary instruments designs experimented showed statistically significant differences in the centering ability (p0.013). TEC/OS was most centered in the canal (0.61) followed by, CEC/OS, TEC/PTN, and CEC/PTN in descending order.

At 9 mm from the apex, the two tested cavity designs and the two rotary instruments designs experimented showed statistically insignificant differences in the centering ability (p 0.117). TEC/OS was most centered in the canal (0.48) followed by, CEC/OS, CEC/PTN, and TEC/PTN in descending order.

TABLE (2) Mean and Standard Deviation (SD) values of Centering Ability of different groups.

Variables	Centering ability						p-value
	At 3mm		At 6mm		At 9mm		
	Mean	SD	Mean	SD	Mean	SD	
CEC/PTN	0.55	0.09	0.44	0.04	0.40	0.03	0.020*
TEC/PTN	0.54	0.12	0.48	0.12	0.39	0.04	0.044*
CEC/ OS	0.50	0.15	0.51	0.06	0.42	0.07	0.294ns
TEC/ OS	0.66	0.13	0.61	0.04	0.48	0.08	0.039*
p-value	0.276ns		0.013*		0.117ns		

****; significant (p<0.05)*** ***ns; non-significant (p>0.05)***

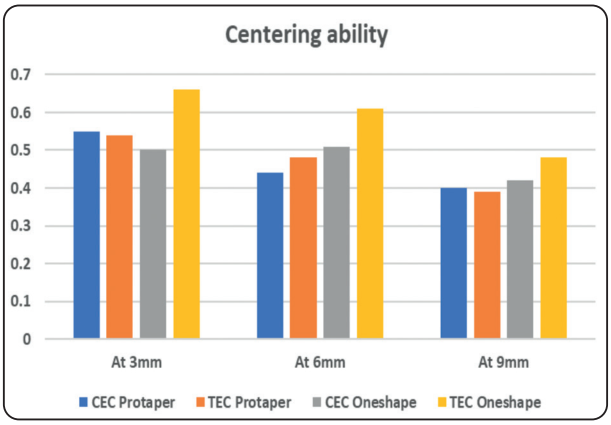

Fig. (5) Bar chart showing the differences in canals' centering ability in three tested cross sectional levels between the two experimented access designs concerning centering ability

DISCUSSION

The present study aimed to contribute to answering the question of whether to proceed with the concept of conservingtooth structure by minimizing unnecessary sacrifice of sound coronal tooth tissues. This raises another question; do conventional traditional accesses really result in zero transportation and perfectly centralized three dimensional shaping of the root canals?. Additionally, is there a significant difference between different NiTi rotary instrumentsdesigns in reaching a relatively centralized non transported preparation?

In recent years, a significant number of research were conducted with the goal of designing a small access cavity that allows for maximum biologic and mechanical canal preparation while minimizing the sacrifice of coronal tooth structure[14,16,22,23].These researches are ongoing aiming to improve natural tooth longevity.

The present study assessed how a CEC design and two dissimilar rotary NiTi systems affected canal shaping parameters-in terms of transportation and centering ability using CBCT. The distal canals were chosen for the experiment based on previous research that specified them as being most affectedby transportation and eccentric preparation when CEC cavity designs are used[14,15]. This was attributed to a lack of distal extension in the original CEC outline, described as a stunted distal extension[14,22].

This study investigated the degree of transportation and eccentricity in the distal canals of molars that were prepared through a contracted access cavity designwith two different rotary instruments designs: PTN and OS. The PTN was chosen for its consistently high reported efficiency and its widespread use in shaping diverse canal anatomies in numerous comparative studies [22,29-31]. OS, is a single file with a reported high cutting efficiency and a variable cutting blade design. Its anti-breakage control along with its electro-polishing that providesincreased flexibility was previously found to be particularly useful in shaping canals through contracted accesses[32]. Additionally, the electro-polishing manufacturing process gives it a high cutting efficiency which is due to different cross sectionsalong the file length.[32,33]

Shaping ability parameters were tested using the Gambill's method since 1996[14,22]. It is a widely used classic method for measuring and evaluating the degree of canal transportation and the ability of instruments to stay centered during canals preparation[27,34-36]. It is almost universally accepted method for testing these parameters and for purposes of comparison as well[37].Nevertheless, both measurements are complementary in describing mathematically, the post-instrumented geometrical canal preservation.

Shaping abilitiesof PTN and OS worked through TEC andCEC designs access cavity were evaluated at three root canal cross section levels; 3,6, and 9mm from the apical constriction. The literaturedoes not provide a standard site for evaluation of shaping ability; it appears that, the region of interest is selected based on the tooth type, root anatomy, as well as studied instruments design characteristics[21,35,36,38]. However; the apical 3 mm is the most significant one for narrow, curved,or wide canals.This is in accordance with previous similar measurements levels[16,22,23,39].

Our results showed that, the maximum calculated transportation at the apical third was found in the CEC group prepared by the PTN file system (mean of 0.146-Fig. 4). Although this is still too low compared to the reported 0.3 mmmaximum value[40]; it should be considered a drawback of CEC as compared to the TEC design prepared with either tested instrument designs. Accordingly, the first hypothesis was rejected. This result confirmed that of Agarwal[41] et al.However, other studies showed higher transportation related to PTN system in general [16,30,42]

Comparing the centering ability for PTN and OS with any of the two access cavity designs, at the apical 3rd mm. canal levels revealed that, TEC prepared with One shape showed significantly the least reduction in the centering ability at all tested canals' levels. This means OS remained centralized in the canal at the most important apical third as well as all over the canals lengths. This result was in accordance with a recent investigation byVakili-Gilaniet al[43]where they found the OS file to maintain the canals'centrality specially at the apical region.

Accordingly, the second hypothesis was partially rejected.

Vorster[44]reported that, there is no definitive evidence in the literature supporting one access cavity design over another. Individual assessment on a case by case policy might help in selection of the best approach for canal cleaning and shaping without much sacrifice for tooth structure.

Conclusions and Recommendations:

Based on the results of the present study, significantly higher transportation values were found for the CECas compared to the TEC irrespective of the rotary instrumentation used. However, centric ability was insignificantly affected by either TEC or CEC modification. Significantly greatest centric ability was found when OS was used in preparation of distal canal through CEC.

It appears that, in contracted access cavities, the preparation parameters depend more on the unimpeded instrumentation accessibility than on the rotary instrument design; at least concerning this specific parameter. Perhaps, in the next generation of intra-canal instrument designs; artificial intelligence will help to solve this problem.

Ethical Approval:

Study has been approved by the local ethical committee at Misr University for Science and Technology-Egypt, with the code FWA00025577.

'Declarations of interest: none'

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to all the individuals and institutions that contributed to the successful completion of this research. Their expertise and guidance were instrumental in shaping the research's direction and methodology.

REFERENCES

1. Patel S, Rhodes J. A practical guide to endodontic access cavity preparation in molar teeth. Br Dent J. 2007; 203(3):133-140. doi:10.1038/bdj.2007.682
2. Siqueira JF, Rôças IN. Clinical Implications and Microbiology of Bacterial Persistence after Treatment Procedures. J Endod. 2008;34(11). doi:10.1016/j.joen. 2008. 07.028
3. Desai H, Stewart CA, Finer Y. Minimally invasive therapies for the management of dental caries—a literature review. Dent J. 2021;9(12):1-27. doi:10.3390/dj9120147
4. Kim S, Kratchman S. Modern Endodontic Surgery Concepts and Practice: A Review. J Endod. 2006;32(7):601-623. doi:10.1016/j.joen.2005.12.010
5. Song M, Shin SJ, Kim E. Outcomes of endodontic micro-resurgery: A prospective clinical study. J Endod. 2011;37(3):316-320. doi:10.1016/j.joen.2010.11.029
6. Del Fabbro M, Taschieri S, Weinstein R. Quality of life after microscopic periradicular surgery using two different incision techniques: A randomized clinical study. Int Endod J. 2009;42(4):360-367. doi:10.1111/j.1365-2591.2008.01534.x

7. Xia J, Wang W, Li Z, et al. Impacts of contracted endodontic cavities compared to traditional endodontic cavities in premolars. BMC Oral Health. 2020;20(1):1-14. doi:10.1186/s12903-020-01237-w

8. Clark D, Khademi J. Modern Molar Endodontic Access and Directed Dentin Conservation. Dent Clin North Am. 2010;54(2):249-273. doi:10.1016/j.cden.2010.01.001

9. Clark D, Khademi JA. Case Studies in Modern Molar Endodontic Access and Directed Dentin Conservation. Dent Clin North Am. 2010;54(2):275-289. doi:10.1016/j.cden.2010.01.003

10. 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. doi:10.5395/rde.2021.46.e46

11. Koohnavard M, Celikten B, Buyuksungur A, Orhan K. Effect of Traditional and Conservative Endodontic Access Cavities on Instrumentation Efficacy of Two Different Ni–Ti Systems: A Micro-CT Study. Appl Sci. 2023;13(9). doi:10.3390/app13095803

12. Shabbir J, Zehra T, Najmi N, et al. Access Cavity Preparations: Classification and Literature Review of Traditional and Minimally Invasive Endodontic Access Cavity Designs. J Endod. 2021;47(8):1229-1244. doi:10.1016/j.joen.2021.05.007

13. Moore B, Verdelis K, Kishen A, Dao T, Friedman S. Impacts of Contracted Endodontic Cavities on Instrumentation Efficacy and Biomechanical Responses in Maxillary Molars. J Endod. 2016;42(12):1779-1783. doi:10.1016/j.joen.2016.08.028

14. Alovisi M, Pasqualini D, Musso E, et al. Influence of Contracted Endodontic Access on Root Canal Geometry: An In Vitro Study. J Endod. 2018;44(4):614-620. doi:10.1016/j.joen.2017.11.010

15. Krishan R, Paqué F, Ossareh A, Kishen A, Dao T, Friedman S. 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):1160-1166. doi:10.1016/j.joen.2013.12.012

16. Bayoumi A, Aly M, Hassan R. Impact of contracted endodontic cavity on shaping ability of protaper next files system by using cone beam computed tomography: an ex-vivo study. Minia J Med Res. 2022;33(2):127-136. doi:10.21608/mjmr.2022.251099

17. Silva EJNL, De-Deus G, Souza EM, et al. Present status and future directions – Minimal endodontic access cavities. Int Endod J. 2022;55(S3):531-587. doi:10.1111/iej.13696

18. Ivanoff CS, Marchesan MA, Andonov B, et al. Fracture resistance of mandibular premolars with contracted or traditional endodontic access cavities and class II temporary composite restorations. ENDO (l Engl). 2017;11(1):7-14.

19. Saberi EA, Pirhaji A, Zabetiyan F. Effects of endodontic access cavity design and thermocycling on fracture strength of endodontically treated teeth. Clin Cosmet Investig Dent. 2020;12:149-156. doi:10.2147/CCIDE.S236815

20. 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):6027-6044. doi:10.1007/s00784-021-04080-7

21. Lima CO, Barbosa AFA, Ferreira CM, et al. Influence of ultraconservative access cavities on instrumentation efficacy with XP-endo Shaper and Reciproc, filling ability and load capacity of mandibular molars subjected to thermomechanical cycling. Int Endod J. 2021;54(8):1383-1393. doi:10.1111/iej.13525

22. Berutti E, Moccia E, Lavino S, et al. Micro-Computed Tomography Evaluation of Minimally Invasive Shaping Systems in Mandibular First Molars. J Clin Med. 2022;11(15). doi:10.3390/jcm11154607

23. Augusto CM, Barbosa AFA, Guimarães CC, et al. A laboratory study of the impact of ultraconservative access cavities and minimal root canal tapers on the ability to shape canals in extracted mandibular molars and their fracture resistance. Int Endod J. 2020;53(11):1516-1529. doi:10.1111/iej.13369

24. Of E, Canal R, Of C, Beam AC, Tomography C. EDJ_Volume 64_Issue Issue 2 - April (Oral Medicine, X-Ray, Oral Biology & Oral Pathology)_Pages 1283-1291. 2018;64:1283-1291.

25. Ghabbani H. Evaluation of the surface nanoscale changes of R-phase, M-wire nickel-titanium instruments after use in extracted molars: An in vitro study. Saudi Endod J. 2021;11(1):14-18. doi:10.4103/sej.sej_18_20

26. Patel B. Ingles Endodontics 7. Vol 45.; 2019. doi:10.1016/j.joen.2019.07.013

27. Barbosa AFA, Silva EJNL, Coelho BP, Ferreira CMA, Lima CO, Sassone LM. The influence of endodontic access

cavity design on the efficacy of canal instrumentation, microbial reduction, root canal filling and fracture resistance in mandibular molars. Int Endod J. 2020;53(12):1666-1679. doi:10.1111/iej.13383

28. Dagna A. Nickel-Titanium Single-file System in Endodontics. J Contemp Dent Pract. 2015;16(10):834-839. doi:10.5005/JP-JOURNALS-10024-1766
29. Donnermeyer D, Bürklein S, Dammaschke T, Schäfer E. Endodontic sealers based on calcium silicates: a systematic review. Odontology. 2019;107(4):421-436. doi:10.1007/s10266-018-0400-3
30. Romeiro K, Brasil SC, Souza TM, et al. Influence of brushing motions on the shaping of oval canals by rotary and reciprocating instruments. Clin Oral Investig. 2023;27(7):3973-3981. doi:10.1007/s00784-023-05022-1
31. Brasil SC, Marceliano-Alves MF, Marques ML, et al. Canal Transportation, Unprepared Areas, and Dentin Removal after Preparation with BT-RaCe and ProTaper Next Systems. J Endod. 2017;43(10):1683-1687. doi:10.1016/j.joen.2017.04.012
32. Dhingra A, Ruhal N, Miglani A. Evaluation of single file systems reciproc, oneshape, and waveone using cone beam computed tomography -An in vitro study. J Clin Diagnostic Res. 2015;9(4):ZC30-ZC34. doi:10.7860/JCDR/2015/12112.5803
33. Dhingra A, Ruhal N, Bhardwaj N, Rohilla S. Single File Systems : A Review. 2015;2(11):2-5. doi:10.17354/ijss/2015/74
34. Pereira RD, Leoni GB, Silva-Sousa YT, et al. Impact of Conservative Endodontic Cavities on Root Canal Preparation and Biomechanical Behavior of Upper Premolars Restored with Different Materials. J Endod. 2021;47(6):989-999. doi:10.1016/j.joen.2021.03.009
35. Hulsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Top. 2005;10(1):30-76. doi:10.1111/j.1601-1546.2005.00152.x
36. Girgis D, Roshdy N, Sadek H. Comparative Assessment of the Shaping and Cleaning Abilities of M-Pro and Revo-S versus ProTaper Next Rotary Ni-Ti Systems: An In Vitro study. Adv Dent J. 2020;2(4):162-176. doi:10.21608/adjc.2020.25190.1059
37. Nagaraja S, Sreenivasa Murthy B V. CT evaluation of canal preparation using rotary and hand NI-TI instruments: An in vitro study. J Conserv Dent. 2010;13(1):16-22. doi:10.4103/0972-0707.62636
38. de Sousa-Neto MD, Silva-Sousa YC, Mazzi-Chaves JF, et al. Root canal preparation using micro-computed tomography analysis: A literature review. Braz Oral Res. 2018;32:20-43. doi:10.1590/1807-3107bor-2018.vol32.0066
39. Yalniz H, Koohnavard M, Oncu A, Celikten B, Orhan AI, Orhan K. Comparative evaluation of dentin volume removal and centralization of the root canal after shaping with the protaper universal, protaper gold, and one-curve instruments using micro-ct. J Dent Res Dent Clin Dent Prospects. 2021;15(1):47-52. doi:10.34172/joddd.2021.009
40. Wu MK, R'oris A, Barkis D, Wesselink PR. Prevalence and extent of long oval canals in the apical third. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000;89(6):739-743. doi:10.1067/moe.2000.106344
41. Jagtap P, Shetty R, Agarwalla A, Wani P, Bhargava K, Martande S. Comparative evaluation of cytotoxicity of root canal sealers on cultured human periodontal fibroblasts: In vitro study. J Contemp Dent Pract. 2018;19(7):847-852. doi:10.5005/jp-journals-10024-2346
42. Gambarini G, Gergi R, Naaman A, Osta N, Al Sudani D. Cyclic fatigue analysis of twisted file rotary NiTi instruments used in reciprocating motion. Int Endod J. 2012;45(9):802-806. doi:10.1111/j.1365-2591.2012.02036.x
43. Vakili-Gilani P, Tavanafar S, Saleh ARM, Karimpour H. Shaping ability of three nickel-titanium rotary instruments in simulated L-shaped canals: OneShape, Hero Shaper, and Revo-S. BMC Oral Health. 2021;21(1):1-7. doi:10.1186/s12903-021-01734-6
44. Vorster M, Van der Vyver PJ, Markou G. Traditional and Conservative Molar Endodontic Access Cavity Designs: A Classification and Overview. South African Dent J. 2022;77(07):407-412. doi:10.17159/2519-0105/2022/v77no7a4.