Dentinal Crack Formation and Quality of Obturation Using Two Single File Systems and Two Obturation Techniques: A micro-CT Study.

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Background and objectives: Root canal preparation following obturation with rotary instruments and different obturation techniques may lead to formation of microcracks in the root canal wall, void and gaps between the canal wall and obturation material.
Aim: This study aimed to evaluate dentinal microcracks and voids formation after using two different files TruNatomy (TRN) and Genius (GN) and two obturation techniques Single Cone (SC) and GuttaCore (GC) using Microcomputed tomography scan (micro-CT).
Methods: 40 extracted mandibular premolars were decoronated, leaving 13mm roots. The roots were randomly divided into two main groups TRN and GN ((n=20)) according to instrumentation, afterwards each group subdivided into two subgroups ((n=10)) according to obturation techniques. The root canals instrumented with TRN and GN file and obturated with Single Cone (SC) and GuttaCore (GC) obturation techniques. AH Plus sealer was used in all groups. The specimens were scanned with Micro-CT before and after root canal preparation and after obturation. subsequently, all pre-and postoperative cross-sectional images of the roots were screened to identify the presence of dentinal defects. Furthermore, the percentage of voids volume calculated. Data were analyzed statistically to determine difference between groups, the level of statistical significance was at $p < 0.05$.
Results: GN revealed the least number of microcracks. There were no significant differences between groups in the incidence of dentinal microcracks. The highest percentage of filling material was observed in GC groups. There were significant differences between the obturation groups in the amount of voids present after obturation ($P < 0.001$).
Conclusion: The instrumentation of root canals induces dentinal microcracks. Obturation have no effect on the formation of cracks. None of the root canal filling procedures yield fillings that are void-free.
Keywords: Dentinal crack, Voids, Micro CT, Guttacore, Singlecone, TruNatomy, Genius.

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INTRODUCTION

The removal of dentin during canal preparation occurs when the files come into contact with the dentinal wall to produce the canal shape. However, root canal instrumentation stress may damage root dentin. Rotary instruments may result in root canal wall microcracks due to constant file contact .[1]
In various scientific research, Dentinal defects during mechanical root canal preparation using motorised nickel-titanium (NiTi) instruments may lead to vertical root fractures and tooth loss. Consequently, identification and comparison of dentinal defect is important.[2]
However, dentinal defects may develop as a result of root canal preparation, obturation, endodontic and retreatment procedures.[3]

Recently, Dentsply Sirona has released a new generation of rotary files known as TruNatomy (TRN). These files come in three different sizes: small; size 20, 0.04 taper, prime; size 26, 0.04 taper, and medium; size 36, 0.03 taper. The TRN instrument has a slip shaping feature that allows for more debridement space, as well as being more flexible and fatigue resistant due to a specific heat treatment and design.[4]

The Genius (GN) instrument system was recently designed as a hybrid asymmetric reciprocation-rotary system (GN; Ultradent Products Inc., South Jordan, UT, USA) containing six endodontic instruments: the Orifice shaper and five shaping files. The manufacturers claim that GN instruments can be used in asymmetric reciprocating in addition to continuous rotating movements. [5]

Furthermore, one of the main goals of endodontic treatment is achieving a hermetic seal of root canals, in order to increase success of endodontically treated teeth.[6] However, the studies had demonstrated the closer relationship between quallity of roots canals obturations and treatment succeed, [7] Poor adhesion may create spaces in the interface between filling materials and dentin, which facilitates bacterial movement in the direction of the apical third of the roots leading to apical periodontitis .[7,8]

Many different materials have been used for obturation of the root canal system, the most common being gutta percha combined with a sealer. Different techniques have been suggested to acheive the best adaptation of gutta-percha to the canals walls.[9]

The single-cone (SC) technique include the introduction of the greater taper gutta-percha cones that closely matching to the shape of rotary nickel - titanium instruments and that technique had gained rapid acceptance.[10] Accordingly, the single-cone (SC) techniques has increasingly grown and gained popular, due to its easy handling, inexpensive, and short procedure time. [10,11]

Before being inserted into the root canals, the gutta-percha is covered with a metallic obturator and oven-heated. This system has undergone various improvements and upgrade the metal core is replaced by a plastic support and more recently, with the cross -linked gutta-percha core obturators. The latest on the market is GuttaCore® (GC) (Dentsply Tulsa Dental Specialties, Tulsa, OK). In comparison to other currently used techniques, this approach promises to be more efficient, safe, biocompatible, and more effective in filling the complexities of the root canal system. [12]

The bulk of existing research on dentinal cracks induced by root filling was based on two-dimensional, destructive conventional models. Accordingly, there was a lacking of non-destructive longitudinal experimental reports on the potential cause-effect relationship between root filling and dentinal micro-cracks. Micro-computed tomography technology (micro-CT) has provided new possibilities for endodontic research by allowing quantitative and qualitative non-destructive assessment of the root canal system before and after endodontic procedures. Micro–computed tomography (micro-CT) applied to endodontics allow 3-dimensional assessment of the quality of obturation, and this makes it possible to identify areas of failure, voids and dentinal microcracks. [13]

METHODS

40 extracted mandibular premolar from adult patients was selected for this study, obtained from several dental clinics in Duhok, Iraq, for reasons unrelated to this study. The teeth were embedded in U-shaped arch of wax and subjected to CBCT for the following inclusion criteria: Teeth with single canal, formed apex, without canal calcification, previous canal treatments, internal; external resorption and type 1 root with term of (Vertucci's classification).[14,15,16] The coronal sections of all teeth were eliminated with a diamond covered bur and water chilling, leaving 13 mm long, soaked in thymol 0.1% and stored at room temperature.[17]

Roots were divided into two main groups TRN and GN ((n=20)) according to instrumentation then each group subdivided into two subgroups ((n=10)) according to obturation techniques SC and GC.

Initial micro-CT:

Each of the samples have been scanned separately for visualization of internal anatomy of the canal (Figure 1) using a micro-CT device Skyscan 1275 (Bruker microCT, Kontich, Belgium). The parameters that to be used have been as follows: an isotropic voxel size of 18 um with a copper-aluminum filter, x- ray voltage of 80 kV and 125 mA, 360 rotations, and a 0.3 rotation step. The samples have been kept at 37 C and 100% humidity for 1 month.[17]

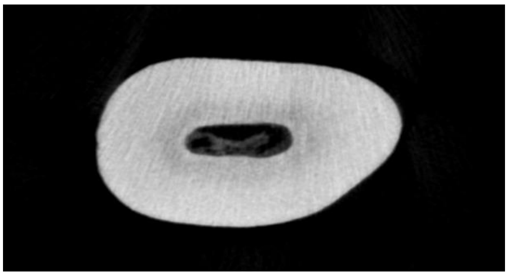

Figure 1: Slice of the pre-instrumentation root image showing internal anatomy of the canal and borders accurately.

The cleaning and shaping started with K type endodontics hands files of # 8, # 10, # 15, and #20 (Dentsply Tulsa, the Dental Specialties). The roots then divide into two main groups TRN and GN ((n=20)):

TruNatomy size 26 0.4 introduced into the canal in brushing motion and continual rotations about (500 RPM) with a torque settings value of (1.5) Newton/centimeters. By using of (VDW electric motor). Genius file size 25 0.4 introduced into the canal in a (90◦) clockwise/ (30◦) counterclockwise hybrid the rotating asymmetric reciprocating motion according to manufacturer (Figure 2). After three pecking motions with the use of 5.25%NaOCl and 17% EDTA then the file removed from canals, and cleaned by steriled gauzes. This process was repeated, until the file's working length is reached. The final irrigation was accomplished for a 1minute with 1mL of 17% EDTA and 30 seconds with 1mL of 5.25% NaOCl and then 1mL of normal saline. Finally, drying the roots canals with paper points size 25 0.4 (5). After the root canal instrumentation, the canal orifice was packed with Teflon.[18]

Figure 2: Genius motor in reciprocation mode.

Secondary micro- CT:

The roots were scanned after instrumentation, with using the same parameter for initial scan.[19,20]

Obturation

Each groups of instrumented roots have been subdivided into two subgroups (n=10) according to obturation technique used.

TRN and GN Single Cone (SC): In the gutta-percha coating technique, matched gutta-percha was used with AH Plus sealer (Dentsply Sirona, Tulsa, OK).

Each canal has been obturated such that it is 0.5 mm shorter than the root end.

TRN and GN GuttaCore (GC): A warm gutta-percha carrier-based system (GuttaCore, Dentsply, Switzerland) introducing it into the root canal by heating a size 25 GuttaCore obturator in the ThermaPrep heater obturator oven (Dentsply, Switzerland) with AH Plus sealer. The GuttaCore obturator was cut at the cementoenamel junction and compacted following the manufacturer's recommendations.

Following the obturation of all roots, they were stored for 1week at 37°C with one hundred percentage humidity in incubator to allow set sealers and sent for final micro-CT using the same parameter for initial and secondary micro-CT. [20]

Microcrack evaluations:

The micro-CT images were transformed in to Data Viewer programs and the sagittal, coronal, and Trans axial section of all samples were obtained, followed by the creation of three-dimensional (3-D) images. The located regions of interesting to all canals is 13mm from the coronal to apex. All of scanning images' views of section were compared before and after instrumentation then after obturation. Sectional views were examined in three categories: coronal 5mm, middle 4mm, and apical 4mm in length respectively, and cracks distribution was presented as a percentage. [16]

Void Evaluation

The DataViewer software version 1.5.2.4 (Bruker-microCT) was used to record three-dimensional image data in axes x, y, and z obtained before and after obturation. The Bruker-microCT software Amira (v.6.0) and MeVisLab v 6.4 (MeVis Medical Solutions AG) were used to create and visualize tridimensional models and quantify root canal volume, filling material volume (gutta -percha and sealer), and voids volume. Using a global threshold method, the gray scale range required to recognize each object under study was determined in a density histogram. To ensure segmentation accuracy, comparisons were made between the original and segmented scans. To generate separate binary images, task lists based on arithmetic and logical operations were used. Calculating the volume of the voids (voids volume overall the canal) by subtracted the filling materials volume (Filling Vol) from the post-obturation roots canals volume (Canal Vol); as

$$Voids\ Vol = Canal\ Vol - Filling\ Vol$$

The voids volume percentage (% Voids Vol) was calculated using the following formula (19):

$$\%VoidsVol = VoidsVol * 100/CanalVol$$

RESULTS

Micro-crack induced after instrumentation

The results of the present study revealed that root canal instrumentation with the TruNatomy and Genius single file system can create dentinal cracks Table 1 and Figure 3. In terms of the total number of slices with new microcracks a lower number of microcracks were found in group that treated with the Genius file systems. The lowest number of slices with new microcracks in teeth thirds were in the apical third (10%) of Genius group. Furthermore, the highest number of slices with new microcrack were found in coronal third of group TruNatomy (25%), it is also worthy to note that, all groups have cracks in the coronal, middle and apical root third regions after instrumentation Figure 4.

Table 1: The percentage and number of dentinal microcracks after canal preparation with TruNatomy and Genius Single file system.

Experimental Group	N	Apical Mean (%)	Middle Mean (%)	Coronal Mean (%)	Total Mean (%)	P value
TruNatomy	20	15 (18.75)	21 (26.25)	25 (25)	61 (23.46)	0.262
Genius	20	8 (10)	17 (21.25)	20 (20)	45 (17.31)	
P value		0.314	0.758	0.738		

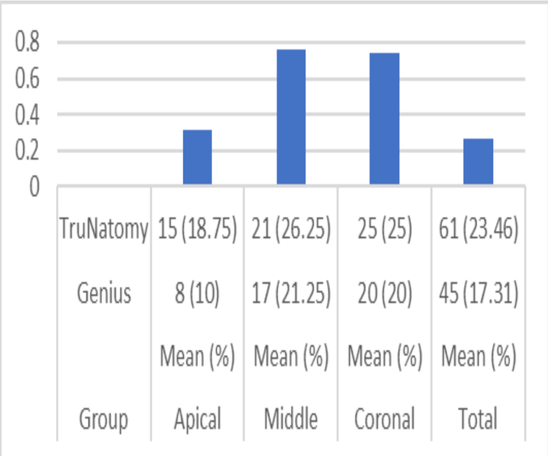

Figure 3: Number and percentage of microcracks induced post-instrumentation.

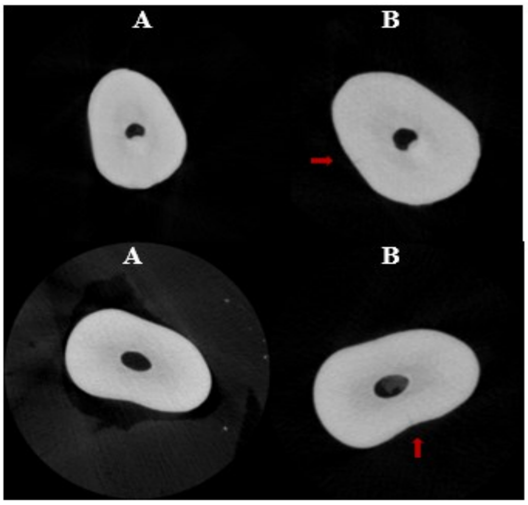

Figure 4: Representative cross-sectional images, showing the existence of dentinal microcrack (red arrows) pre-instrumentation (A), post-instrumentation with Genius single file system (B), in coronal tooth thirds.

Micro-crack induced after Obturation

In the post-obturation analysis, the frequency of microcracks at coronal, middle and apical root third remained unchanged following canal preparation for all groups (Figure 3).The outcome of micro-crack induced by obturation techniques shows that only the TruNAtomy Guttacore technique was associated with one new crack formation after obturation Figure 5.The outcomes of the Kruskal-Wallis H test revealed that there were no significant statistical differences between the four groups of obturation in number of new slices with microcrack in the apical, middle and coronal third Table 2.

Table 2: The percentage and number of dentinal microcracks after root canal obturation with SC and GC obturation techniques, previously prepared with TRN and GN rotary files.

Experimental Groups	Obturation				
	Apical Mean(%)	Middle Mean (%)	Coronal Mean (%)	**Total Mean (%)**	P value
TruNatomy Single Cone	6 (15)	6 (15)	5 (10)	**17 (13)**	**0.07**
TruNatomy Guttacore	9 (22.5)	15 (37.5)	21(42)	**45 (36)**	
Genius Single cone	4 (10)	8 (20)	8 (16)	**20 (15)**	
Genius Guttacore	4 (8)	9 (22.5)	12 (30)	**25 (19)**	
P value	0.555	0.303	0.281		

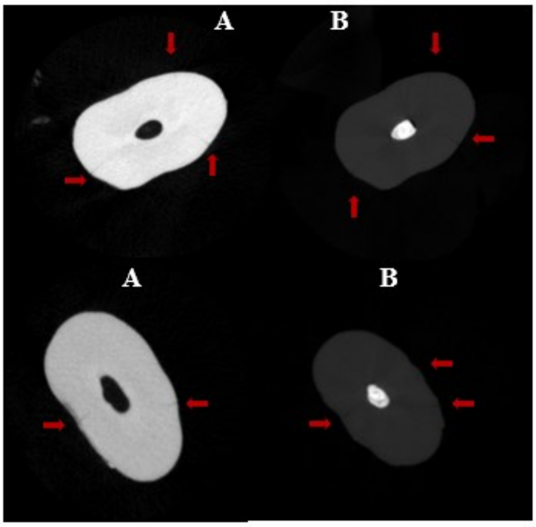

Figure 5: Representative cross-sectional images, showing the existence of dentinal microcrack (red arrows) post-instrumentation with TruNatomy single file system (A), post-obturation with GuttaCore obturation technique (B), in coronal tooth thirds.

Regarding intragroup compression there were no statistical significan- differences found between each sub-group (Table 3).

Quality of Obturation

Mean percentage values ± SD of filling materials and voids are summarized in Table 4 and Figure 6. All filling techniques demonstrated good filling ability Figure 7 and 8.

It is evident from (Table 4) that lowest mean volume(Void) was in group TruNatomy GuttaCore followed by group Genius GuttaCore, TruNatomy Single Cone and Genius Single Cone respectively.

TruNatomy GuttaCore showed the best results regarding the void formation and it was statistically significant different from all other groups. While, there was no statistically sinnificant different between TruNatomy Single Cone and Genius Single Cone. Additionally, the presence of voids within the canal makes the guttacore technique significa ntly different from the single cone techni que overall Table 5.

Table 3: Intragroup comparison of dentinal Micro-crack induced after obturation between experimented groups at the apical, middle and coronal tooth thirds

Expremental Groups		Mean (%)	P value
Genius Single Cone	Apical	**4 (10)**	0.2
	Middle	**8 (20)**	
	Coronal	**8 (16)**	
Genius Guttacore	Apical	**4 (10)**	0.968
	Middle	**9 (22.5)**	
	Coronal	**12 (24)**	
TruNatomy Single Cone	Apical	**6 (15)**	0.12
	Middle	**6 (15)**	
	Coronal	**5 (10)**	
TruNatomy Guttacore	Apical	**9 (22.5)**	0.758
	Middle	**15 (37.5)**	
	Coronal	**21 (42)**	

Table 4: Mean and Sd. of Volume (void in mm3) in all groups

Tools	N	VOIDS mean ± Sd.	Sig.	Groups
TruNatomy Guttacore	10	0.786 ± 0.0109	**0.001 (**)**	**A**
TruNatomy Single Cone	10	1.727 ± 0.1467		**C**
Genius Guttacore	10	1.215 ± 1.3668		**B**
Genius Single cone	10	1.916 ± 0.288		**C**

*Different uppercase letters: statistically significant differences

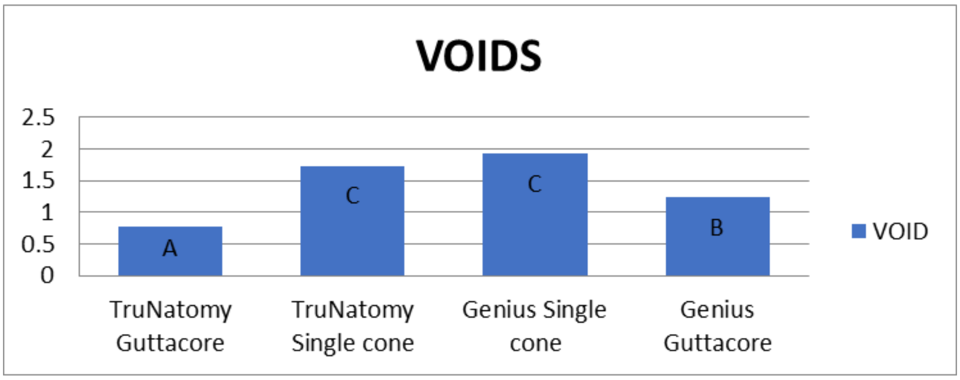

Figure 6: Mean and Sd. of Voids in all groups.

Table 5: Mean and Sd. of Void (void in mm3) in Single Cone and GuttaCore obturation technique groups.

Experimental Groups	Guttacore	Single Cone	P value
Mean	1.0005	1.8215	0.000
SD	0.4391	0.7103	
N	20	20	

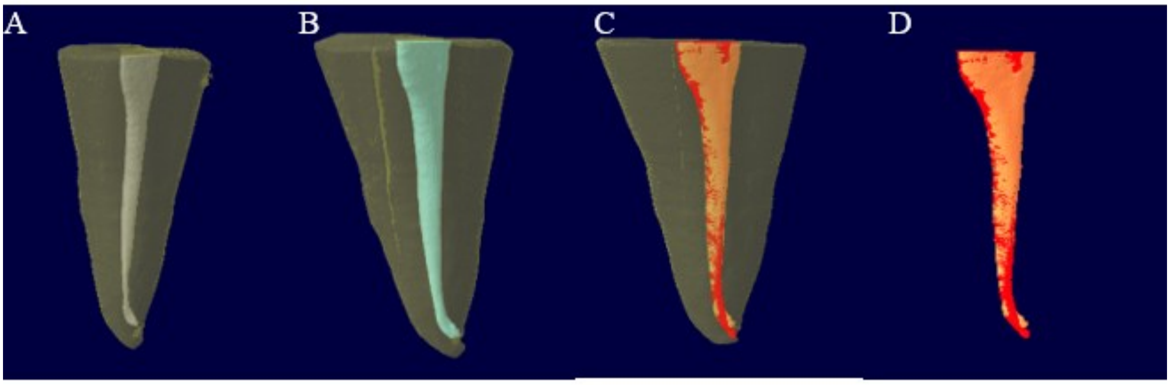

Figure 7: 3D model of a sample filling using single-cone technique in partially oval shaped canal observed in four scan A: Natural B: Post-instrumentation C: Post-obturation D: Obturation material within the canal.

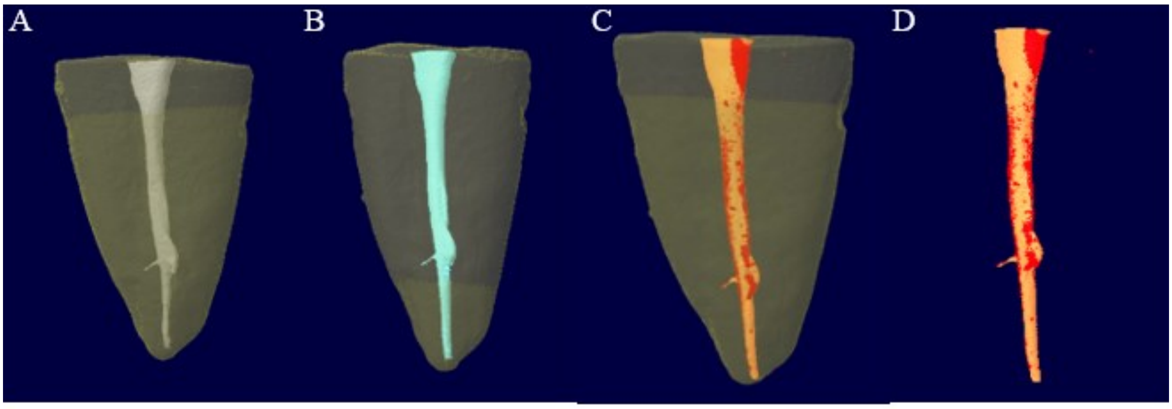

Figure 8: 3D model of a sample filling using Guttacore technique in partially oval shaped canal observed in four scan A: Natural B: Post-instrumentation C: Post-obturation D: Obturation material within the canal.

DISCUSSION

Following endodontic therapy, VRF is one complication that leads to poor prognosis of the obturated teeth.[22, 13] Yan *et al.* (23) reported that VRF is most likely to occur by the transmission of an existing dentin defects such as micro-cracks or craze lines when they are continuously subjected to stresses. Although many iatrogenic and non-iatrogenic factors are suggested to plays a vital role in the occurrence of dentin microcracks in root canal treated teeth, mechanical and chemical disinfection, obturation, post-placement, and post endodontic restorative procedures are considered as potential causes.[24]

Biomechanical preparation with hand or rotary files causes stress and strain on root dentin walls and might result in microcrack occurrence. The degree of microcrack formation may depend on the number of files used, taper, pitch, cross-section design, flexibility, and other metallurgical features of the instruments.[25] Obturation techniques used in endodontics force the root filling materials into the root canal. These forces may result in microcracks or craze lines, which may develop into VRFs. Sectioning and microscopic examination were used in earlier studies associated with false-positive results, hence in the current study, nondestructive micro-CT evaluation was chosen.[17]

In this study, extracted mandibular premolars were used because their smaller dimensions and thin dentinal walls are more prone to the forces generated during instrumentation. If large tapered files cannot induce cracks in mandibular premolar, chances of rotary files inducing cracks in other teeth are unlikely.[14]

The roots were embedded in polyvinyl siloxane in an attempt to mimic periodontal conditions that may change the force distribution pattern around the tooth when external forces are used in obturation. However, the actual clinical situation may be more complex.[26]

Crowns were decoronated to flat surface for better organization and determining the working length accurately. [27]

Higher concentrations of NaOCl solution significantly decrease the elastic modulus and flexural strength of human dentin compared with physiologic saline and solutions of lower concentrations.[8] Henceforth, the use of 5.25% NaOCl solution was considered for irrigation purpose.

The first part of this research aimed to compare the microcrack incidences during the biomechanical preparation and obturation of a root canal using different thermomechanically heat-treated rotary files with different kinematic motions and sequences, and different obturation techniques through a non-destructive imaging methodology.

There was no statistically significant difference between the two-rotary file system TruNatomy and Genius in inducing dentinal microcracks formation, all nickel-titanium rotary instrument systems were associated with microcracks (Table 1), this may be due to the high-tapered designs of rotary Ni-Ti instruments and the greater number of rotations in the canal needed to complete a preparation.[29] Furthermore, no statistically significant difference was seen between crack formation at apical, middle, and coronal third (Table 1). However, the Genius file system had significantly fewer microcracks when compared with the TruNatomy, these findings are in accordance with previous reports (Govindaraju et al.,2017, Oliveira et al., 2020, Shantiaee et al., 2021). This could be due to the low torsional and bending forces generated by the reciprocal movement compared to the continuous rotational movement.[33] Both TruNatomy and Genius files showed the highest prevalence of crack in the coronal third compared to middle or apical third. Versluis et al., (2006) also concluded that the stresses generated at 1 mm short of the apical foramen were one third of stresses at more coronal levels. This may be due to increase in taper of various files towards the coronal third.

This finding is in line with previous micro-CT studies demonstrating no influence of root canal preparation with single reciprocating and rotating file systems on the formation of microcracks. [21,34,54,59.]

Similar to current study Pedullà et al., 2017, Cassimiro et al., 2018, Shantiaee et al., 2019, Anous et al., 2020, Koroth et al., 2021 and Mohamed et al., 2021 concluded that all rotary instruments can cause dentinal crack regardless of motion type.[36-41] These results were similar to the results of Harandi et al., (2017) and Khoshbin et al., (2018),[13,35] who concluded no statistically significant difference was seen between crack formation at apical, middle, and coronal third Table 3.

These results confirm the claim of Shemesh et al. (2009; 2010), Karataş et al. (2015), Daokar et al., (2016), Harandi et al. (2017), Saha et al., 2017, Li et al. (2018), Pandey et al, (2021) and Deopujari et al., (2022) that the significant increase in the appearance of defects after preparation alone when compared to nontreated control group. [13,42-49]

Similar to current findings Pawar et al., (2019), Fráter et al., (2020) and Arumugam et al., (2021), [50-52] concluded that no association was determined between the kinematic motions and sequences of the rotary instrument with regards to the types of dentinal defects observed on the extracted mandibular premolars. Therefore, the selection of the rotary file systems to be used in a clinical setting would depend on other factors such as shaping ability, cost and clinician preference.

In contrast, studies (Bürklein et al., 2013, Liu et al., 2013, Karatas et al., 2015, Karatas et al., 2016) reported that different movement kinematics and NiTi systems were associated with various amounts of dentinal microcracks. [40,56-58,]

On the other hand, contradictory findings were reported in several studies where the microcracks was not noted after canal preparation (De-Deus et al., 2015, Bayram et al., 2017, Aksoy et al., 2019, Aydın et al., 2019, Arumugam et al., 2021). 1,2,52-54

Microcrack formation due to the shaping motion is negligible and unpredictable. Moreover, the synergistic effect of kinematic and other factors, such as NiTi alloy and geometric features, influence microcracks. Less dentinal damage is reported in some studies for reciprocating motion than continuous rotation Liu et al, 2013, Ashwinkumar et al. (2014), Kansal et al. (2014), El Nasr and El Kader (2014) and in reverse Bürklein et al, 2013b showed that reciprocating instruments were associated with more dentinal cracks than full-sequence rotary systems.[25,33,57,60]

The outcome of micro-crack induced by obturation techniques shows that only the TruNAtomy Guttacore technique was associated with one new crack formation after obturation (Table 2) (Figure 5). Statistically, no significant difference was found between all groups. Micro-cracks noticed after the biomechanical preparations were consistent with the postobturation micro-CT images for all the groups without propagating root defects. A slight increase in one new crack slices in TruNatomy group could be due to the high compaction force used when compared to the other groups despite the Genius guttacore group, while the single -cone technique applying minimal pressure compared to the other filling techniques that create compaction forces on the root canal walls; it is not associated with an increase in microcracks after obturation.

In agreement to current study Çapar et al. (2015) and Chellapilla et al., (2021) reported that the obturation technique did not induce new crack formation in root dentin. [62]

In contrast, Kumaran et al., (2013), Jain et al., (2018) and Aydinbelge et al., (2019) reported that obturation procedure lead to the induction and propagation of dentinal microcracks. [18,64]

Quality of obturation (Voids)

Voids and gaps within root canal fillings can be influenced by several factors, such as the experience of the clinician, the root canal mechanical preparation technique, differences in irrigation methods, the selected filling technique, the physical properties of the selected sealer, the focused anatomy configuration of the root canal system, the use of different scanning devices, diverse calculation softwares and so on. We speculated that these factors may be reasons for the differences between other studies and the outcomes of this research.[64]

The single-cone technique in both groups TruNatomy and Genius showed a high frequency of total voids and a statistically significant difference with the GuttaCore groups (Table 4). These results may be due to greater coronal leakage with the single-cone (SC) technique that greater amount of sealer used in comparison with thermoplasticised gutta-percha. The single -cone technique poses a major risk of void formation from an imperfect adaptation of a single master cone to the middle and coronal third of the canal, as well as the SC technique lacks vertical and lateral pressure during the obturation procedure.

Castagnola et al, (2018) confirmed that single-cone is a simple technique, suitable for a narrow and circular canal or for a canal prepared with a tapered circular preparation. This technique cannot be employed in larger diameter root canals and oval-shaped canals to avoid the formation of voids. [65]

When Single Cone and the GuttaCore core-carrier technique were compared (Figure 7 and 8), in which non-destructive method of investigations identified significant lower percentages of voids in canals that were obturated with GuttaCore core-carriers. GuttaCore represents the latest generation of carrier-based root canal filling material that uses thermoplasticised gutta-percha as the core material. Studies on the previous generation of this class of carrier-based obturators, ThermaFil Plus, yielded favourable results in terms of their adaptation to canal walls, although void-free fillings in oval-shaped canals were not consistently achieved.[66]

Moreover, in both groups GuttaCore techniques exhibited the lowest frequency and volume of total voids (Table 5). This result is in agreement with Yadav et al., (2020) who found that the GuttaCore technique produced excellent results in comparison with a cold gutta-percha technique, in addition, use of heat- softened gutta percha resulted in a better homogenous mass with less voids and improved adaptation to the canal walls.

The genius guttacore group showed more void than the TruNatoomy guttacore group, the fact that we used a guttacore obturator on the genius group instead of the its individual obturator may be the reason why the genius guttacore group displayed greater void than the TruNatoomy group of guttacore.

Similar to Schäfer et al., (2016) who reported a statistically significant difference in the percentage of voids between the thermoplastic and cold techniques. [68]

The results of this study contradict with results of Gavini., (2017),[69] who showed no significant differences were found in the term of voids when comparing the SC with the thermoplastic technique.

However, AH Plus sealer showed a slight increase of void percentage in the simulated root canal over time. Analysis of the void percentage distribution in each area indicated that the main cause of this change was the significant increase in the void percentage in the apical area of the AH Plus sealer. One of the factors for this increase may be the solubility of the sealer, sealer dissolution and not expansion or shrinkage.[70]

CONCLUSIONS

Based on the results of this study, the instrumentation of root canals with TruNatomy (Rotation) and Genius (Reciprocation) single file systems induce dentinal microcrack formation.

No change in the number of micro-cracks was recorded after obturation with Single Cone and GuttaCore techniques ($P > 0.05$). The two obturation techniques were not statistically different in the occurrence of micro-cracks after obturation.

Our findings suggest that none of the root canal filling techniques used produce void-free fillings. The Guttacore yields superior obturation quality to that of SC.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest relevant to this article.

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