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EFFECT OF DIFFERENT NICKEL–TITANIUM ROTARY SYSTEMS ON DENTINAL CRACK FORMATION DURING ROOT CANAL PREPARATION IN PRIMARY MOLARS: AN IN VITRO STUDY

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ABSTRACT

Mechanical preparation of primary teeth root canals was associated with dentinal micro-cracks that might evolve into vertical root fracture compromising treatment success and shift treatment toward dental extraction. Consequently, the objective of current study was to assess and compare the dentinal crack formation of Kedo-SG Blue file and Wave-One Gold to Stainless Steel hand K files after root canal preparation of primary molars.

Materials and methods: Seventy-five mandibular second primary molars with two separate and straight mesial canals were chosen and immersed in distilled water. Removal of coronal portions and distal roots of all teeth were carried out utilizing a diamond coated bur with water coolant. All teeth were randomly allocated into three groups (n=25 /each) according instrumentation file: (1) Kedo-SG Blue, (2) Wave-One Gold and (3) Stainless Steel hand files. Then, all specimen were cut perpendicular to the axis of tooth to coronal, middle and apical third, therefor, three slices were obtained from each specimen. Each slice was examined with Environmental Scanning Electron Microscope (E.SEM) to determine the presence/absence of cracks. Statistical analysis was carried out with R statistical analysis software version 4.0.3 for Windows.The level of significance was set at $p \leq 0.05$. **Results**: The majority of samples instrumented with Kedo SG Blue 57(76.0%), Wave one gold 44(58.7%) and Stainless Steel k file 65(86.7%) were free of cracks.

Conclusions: Higher percentages of dentinal cracks were seen in the WOG group followed by Kedo-SG Blue group, with lowest percentages recorded for Stainless Steel hand K –files group.

KEYWORDS: Dentinal crack; primary teeth; Stainless Steel k file; Wave One Gold; Single file system; Kedo-SG Blue; SEM.

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INTRODUCTION

In children, primary teeth have an essential role for mastication, esthetics, phonetics and moreover as a natural space maintainer for permanent successors. Problems in primary teeth like pain and/or swelling often lead to child distress during mastication and speech. Also may affect child appearance, psychology and interaction with peers[1].

Primary teeth with advanced pulp degeneration could be extracted or treated with pulpectomy procedure which was considered as a viable long-term option for management of irreversibly inflamed or necrotic primary teeth with a success rate of about 89% after 24 months follow up[2]. Mechanical shaping during pulpectomy procedure could be performed with hand stainless steel files or Nickel titanium ones [3].

The concept of single-file approach was newly proposed in endodontics, and its implementation in endodontic treatment of primary teeth has now been argued [3,4]. One of them is Wave One Gold **(WOG) (Dentsply, Maillefer, Ballaigues, Switzerland)**, it is a modification to Wave One file meanwhile maintaining the reciprocal file movement, the geometry, cross-section, and dimensions of file were altered. The file's cross-section was changed to a parallelogram along with two cutting edges. Moreover, the off-center design utilized in WOG files [4].

The most notable alteration in files is the production utilizing gold heat approach. Gold heat approach is relying on reverse of the M-Wire technology, that uses the treatment of pre-production heat and via file heating following production and then cooling it in slow manner. In accordance with the manufacturer company, this contemporary heat treatment raises the files flexibility [5].

The design of Kedo files system **(Reeganz dental care Pvt. Ltd. India)** is done to be compatible for preparation of root canal in primary teeth. Kedo files are provided in two types which are Hand type (Kedo - SH) and rotary type (Kedo - S, Kedo – SG, Kedo – SG BLUE). Kedo SG Blue (controlled memory file) comprises of three Ni-Ti rotary files with a triangular cross section and a non-cutting tip. The file's length is 16 mm. The working length of the files is 12mm. The files are called as D1, E1, U1, sequentially corresponding to their use; **D1 file:** has a tip diameter of 0.25 mm with a changeable taper. It is capable of being utilized in primary molars with narrow canals (disto-buccal canal in maxillary molars and mesial canals in mandibular molars), **E1 file:** possesses a 0.30 mm tip diameter and can be utilized in broader molar canals (palatal canal in maxillary molars and distal canal in mandibular molars), and **U1 file:** possesses a 0.40 mm tip diameter and utilized in primary incisor teeth [6].

However, mechanical preparation of primary teeth root canals usually associated with dentinal micro-cracks which might develop into vertical root fracture compromising treatment success and shift treatment toward dental extraction of affected tooth. Many factors were suggested to control this complication such as technique of instrumentation, type of motion and apical size preparation [7].

Literature review revealed controversial findings for effect of different file systems which differ in metallurgy, motion and apical preparation performance in developing of dentinal micro-cracks in root canal walls. Also, limited trials that compare dentinal micro-cracks development by different file systems in root canals of primary teeth were available.

Therefore, the current study was conducted to evaluate and assess the dentinal crack formation of Kedo-SG Blue file (rotation motion) and Wave-One gold (reciprocation motion) in comparison with stainless steel hand K files after preparation of root canal in primary molars using Scanning Electron Microscope (SEM).

MATERIALS AND METHOD

The current study was performed at the central laboratory for micro-analysis, Faculty of Dentistry, Minia University.

Specimens collection and selection

Out of 100 examined primary mandibular second molar, 75 teeth with at least two thirds of intact mesial roots were selected for the study. Teeth were extracted due to periapical pathology or preventive orthodontic approach. Parents / care givers of the patients signed informed consent for their approval to use teeth in the study.

Teeth preparation

After collection and selection of teeth, hard and soft tissues surrounding the teeth were removed mechanically utilizing a periodontal curette. The chosen teeth were immersed in distilled water at room temperature. Then they were immersed in 0.5% sodium hypochlorite **(PPH CERKAMED, Stalowa Wola Poland)** for one day for disinfection then kept in distilled water at room temperature. The coronal portions and distal roots of all teeth were removed with diamond coated bur **(Dentsply, Maillefer, Ballagues, Switzerland)** under water cooling and mesial roots were utilized for the study.

A stereomicroscope was used to inspect all roots **(Olympus BX43, Olympus Co., Tokyo, Japan)** and any with preexisting craze lines or cracks were excluded. Subsequently, the roots were covered with aluminum foil then inserted into acrylic resin **(Imicryl, Konya, Turkey)** [8]**.** Thereafter, roots were removed from the resin, and the foil was detached. The blocks of resin were loaded with viscous silicon impression material **(Express XT Light Body Quick; 3M ESPE, Neuss, Germany)** in order to mimic the periodontal ligament, and subsequently the specimens returned into the resin blocks again.

Randomization, allocation and grouping the specimens

All selected samples were assigned a numerical denotation (1–75). Then, they were randomly allocated into 3 groups (25 each) by computer generated block randomization according to instrumentation file that will be used for canal preparation as follows:

Group I: Kedo-SG Blue system **(Reeganz dental care Pvt. Ltd. India)**

Group II: Wave One Gold (WOG) **(Dentsply, Maillefer, Ballaigues, Switzerland).**

Group III: Stainless Steel hand K –files **(Dentsply-Maillefer, Dentsply lima,swiss).**

Root canal preparation

Penetration of root canals was performed utilizing #10 K-file (Dentsply Maillefer) till the file's tip was observed from the apex. The working length was determined to 1 mm shorter than this length.

Group I (N=25)

In accordance with the manufacturer instructions, root canals were prepared using the Kedo-SG BLUE file system (D1 file). The typical speed of rotation is 250 - 300 RPM. The torque needed is 2.2 - 2.4 Ncm**.**

Group II (N=25)

Root canals were instrumented according to manufacturer instructions with the Wave One Gold Primary (25/.07) reciprocating single-file system and the torque-controlled endodontic motor in the "Wave One ALL" program. The rotary files were rotated in a16:1 speed reduction head piece Powered by krafit Endo A Class motor **(Saeyang Microtech Co., korea.**

Group III (N=25)

The root canals were prepared manually with stainless steel K -files with step-back technique in sequential manner up to size#30. This group served as positive control.

Irrigation of root canals in the three groups was carried out with a freshly mixed 1% sodium hypochlorite (NaOCl) solution. All files were lubricated with EDTA gel 17% **(Dolo, prevest Denpro, India)** each time they used for canal preparation **.**

Sectioning and microscopic examination

Utilizing a water-cooled, low-speed saw **(Isomet; Buehler Ltd, Lake Bluff, IL, USA)**, the roots of 75 teeth were cut perpendicular to the axis of tooth at cervical, middle and apical thirds, and three slices were obtained from each root. The teeth were kept in distilled water throughout the experiment to avert any artifacts caused by dehydration.[9]**.**

Dentinal micro-crack evaluation

After sectioning, the specimens were subjected to Environmental Scanning Electron Microscope (E.SEM) for evaluation .

Definitions of the defects (Harandi A et al., 2017) [10]

"No crack" was defined as root dentin with no cracks or lines of craze either at the root canal wall's internal surface or the root's external surface. **(Fig.1.a)**

"Crack" was defined as whole lines seen on the slice that either spread from the lumen of root canal to the dentin or from the outer surface of root to the dentin**. (Fig.1.b)**

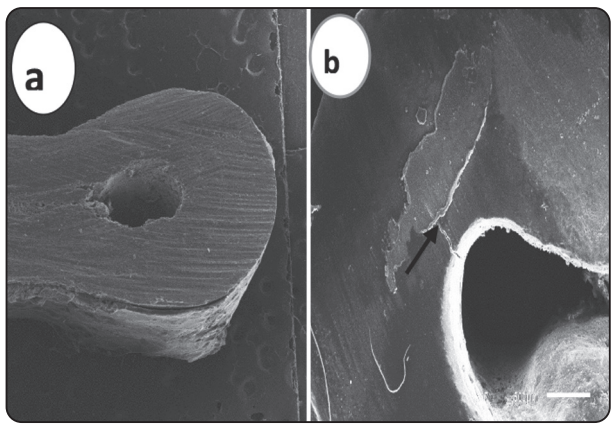

Fig. (1) **(a)** Specimen showing absence of dentinal defect following root canal preparation, (b) Specimen showing presence of dentinal defect following root canal preparation.

Statistical analysis

Percentages (%) was used to present the categorical data. Fisher's exact was used for statistical testing. Pairwise comparisons were done utilizing multiple z-tests with Bonferroni correction. The level of significance was determined at $p \leq 0.05$ for all tests. Statistical analysis was carried out with R statistical analysis software version 4.0.3 for Windows.

RESULTS

225 tooth slices underwent examination in this study. The distribution of dentinal cracks formed by the examined file system amid the coronal, middle, and apical regions is presented in **Table (1)**. The results from this study showed that manual and rotary groups develop crack after root canal preparation. However, there were statistical significant differences between different file types in coronal, middle and apical where **P=0.043 ,0.003, 0.013** respectively.

The Overall percentage of cracks in all sections were 41.3%, 24.0%, and 13.3% for WOG, Kedo SG Blue and K-file groups respectively. Regarding total number of cracks in all sections, WOG showed statistically significant more dentinal cracks than Stainless steel hand K files **(P<0.001)**, but no statistically significant difference with Kedo SG Blue **(P>0.05)**.

WOG file demonstrated statistically significant difference with Stainless Steel K-file in coronal and apical third (P<0.001), with no statistically significant difference at middle third. Also, WOG was statistically a significant difference with Kedo SG Blue in middle third only (P<0.001).

Kedo SG Blue showed no statistically a significant difference with stainless steel K-file in coronal and middle, but there was statistically a significant difference at apical third of the root (p<0.001).

TABLE (1) Frequencies of dentinal defects at different parts of the root among studied groups

File type		Coronal n (%)	Middle n (%)	Apical n (%)	Total n (%)
Kedo SG Blue	Crack	10^{AB}**(40.0%)**	0^{B} **(0.0%)**	8^{A} **(32.0%)**	18^{AB}**(24.0%)**
	No crack	15**(60.0%)**	25 **(100.0%)**	17 **(68.0%)**	57**(76.0%)**
Wave One Gold	Crack	15^{A}**(60.0%)**	9^{A} **(36.0%)**	7^{A} **(28.0%)**	31^{A} **(41.3%)**
	No crack	10**(40.0%)**	16 **(64.0%)**	18**(72.0%)**	44(58.7%)
Stainless steel k file	Crack	6^{B} **(24.0%)**	4^{AB} **(16.0%)**	0^{B} **(0.0%)**	**10^{B} (13.3%)**
	No crack	19 **(76.0%)**	21 **(84.0%)**	25**(100.0%)**	65(86.7%)
P value		**0.043***	**0.003***	**0.013***	**<0.001***

-*; significant (P ≤ 0.05) ns; non-significant (P>0.05)

-Percentages with different superscript letters within the same vertical column are statistically significantly different.

DISCUSSION

Conventionally, preparation of root canal was performed utilizing manually manipulated stainless steel endodontic files. Recently, Enhancements in rotary nickel titanium tools have given the opportunity to new techniques and designs of root canal preparation. But the main disadvantages correlated with rotary nickel instrumentation is the occurrence of dentinal defects in form of micro cracks and craze lines that further may lead to vertical root fracture (VRF) [11]**.** The tip design, cross-section geometry, progressive or constant taper type, flute of files and constant or variable pitch are all factors that may be related to such defect [12]**.**

Several studies have evaluated the stress applied to dentin and micro-crack formation in use of rotary systems in permanent teeth [13-17]**.** However, studies on primary teeth are limited. Therefore, the current study was carried out to assess and compare effect of two single file systems with rotational (Kedo SG blue) and reciprocal (Wave One Gold) movements on formation of dentinal crack within preparation of root canal of primary molars. The manual stainless steel K files were used as a control due to their traditional use for canal preparation of primary teeth.

Single file system was selected because it showed equal or superior root canal cleaning efficacy, reduced stresses, avoided the risk of cross-contamination and less damage to root canal walls compared to multi-file systems, in addition they can save time and cost [18,19]**.**

Mandibular primary molars with at least two thirds of intact mesial roots were included in this study in accordance with ***AAPD,.2020*** [20] guidelines regarding indications for performing of pulpectomy procedure in primary molars and also to allow assessment the dentinal crack formation at different levels of the root canal.

Selected teeth were cut along their long axis in perpendicular manner, to allow assessment of effect of root canal instrumentation procedures on dentin root via direct root inspection [21, 22]. Prior to instrumentation procedures, selected roots were examined to exclude those with any cracks or crazes which may developed during extraction or teeth sectioning process to insure validity of the results.

The mesial root of primary mandibular second molars were selected for instrumentation to ensure homogeneity of specimens, also all instrumentation procedures were carried out by a single operator to

provide consistent and reproducible technique for all samples.

One % NaOCl solution was used for canal irrigation to protect dentine's microstructure and to make sure that the dentinal cracks were primarily linked to the mechanical preparation, greater concentrations of NaOCl solution was reported to decrease the elastic module and hardness level of dentin [23].

In addition to that, the roots were encompassed with a material of impression to imitate the bony socket which may alter the distribution of force surrounding the tooth whenever external forces were utilized. Nevertheless, the clinical condition is more complicated due to periodontal ligament's presence which could additionally affect the forces distribution [7].

Environmental Scanning electron microscope was selected for evaluation of micro-cracks development in three areas; coronal, middle, apical thirds of the root. It was selected for evaluation in the current study since it has several advantages over other available methods including; 1) detection of micro-cracks using direct inspection technique, 2) being a well-accepted method to examine the endodontic instruments' impact on the morphology of dentine surfaces, 3) offered high-resolution images of 45x magnification for micro-cracks detection [9,11,24].

The results of the current study showed that manual and rotary groups developed cracks after preparation of root canal but there was a statistical significant difference between different file types ($P<0.001$). 86.7% of samples instrumentsd with stainless steel K file, 76% of Kedo SG Blue samples and 58.7% of Wave one gold were free of cracks were free of cracks. Also, K stainless steel files demonstrated statistically significant lowest frequency of micro-cracks formation in coronal and apical thirds than both other tested files with a statistically significant differences.

The results were in agreement with ***Kim, 2013*** [25] ***and Das, 2018*** [23] who demonstrated that K files produced lower percentage of micro cracks than different rotary file systems which could be attributed to a greater number of active rotations associated with rotary systems, greater taper of rotary files (7-3 % for wave one gold and 8 - 4% for Kedo SG Blue) compared to standard K ones (2% taper) and greater total volume of root dentin removal with Ni-Ti rotary systems [26,27].

The highest percentage of crack formation was observed in coronal third of the roots in all groups (24%, 40%, 60% for K-file, Kedo SG blue and one wave gold files respectively), this could be attributed to high concentration of tension on the bucco-lingual extensions during canal preparation[28]. The same finding was recorded in other studies[29,30].

On comparing the two rotary files, it was found that Kedo SG Blue files showed lower percentage of micro-cracks formation than Wave One Gold files. The cross-section of WOG single file causes alternative touches on the dentin with 2 and 1 edges within a 360° rotation. As a result, the instrument's contact with the dentinal walls, may raise and encouraging the dentinal defects formation [22].

On the contrary, ***Kansal et al., 2014*** [31]***, Jamleh et al., 2015*** [32] announced that continuous rotary instruments caused more cracks than reciprocating instruments, they attributed this to the fact that the alloy from which the instrument is manufactured was an essential factor in terms of determination of the damaging possibility of single-file instruments rather than the instrumentation motion as WOG was gold wire [33].

Regarding crack formation at different parts of the root, the results revealed statistically significant differences, where lower percentage of micro-cracks formation was observed in roots instrumented with Kedo SG Blue files at middle and coronal thirds than Wave One Gold files. This could be attributed to the difference in the cross sectional design which can impact the number of times that it touches the root dentin, forming the possibility to induce various tension degrees. Wave one gold files had the greatest percentage of touches on the dentin in middle and coronal sections [28,34].

However, Wave One Gold files demonstrated a lower frequency of micro-cracks formation than Kedo SG blue files at apical third without a statistically significant difference, which may be attributed to the difference in the initial tapers of both files; The Kedo SG Blue file had an initial tip with 8% taper, whilst the WOG file had an initial taper of 7% .

In the present study, a number of strength points could be addressed as: 1) using adequate sample size for comparing of the study groups, 2) strict adherence to standardization measures such as using only mesial roots of lower second primary molars with at least intact two thirds, 3) exclusion of any roots with cracks or crazes before instrumentations 4) all procedures were carried with same operator in same manner and 5) blinding was confirmed for observer who performed scanning and for statistician (double blinded).

While the limitations of this study included difficulty to simulate periodontal ligaments which could additionally impact the forces distribution and crack propagations. Also, only mesial roots of second primary molars were tested.

CONCLUSIONS

On the basis of the results of the current study, the followings can be concluded:

1. Hand instrumentation with K files (2% taper) caused the least number of dentinal micro crack formation than both rotational and reciprocating Ni-Ti files
2. Wave One Gold produces highest percentage of root dentinal cracks compared to Kedo SG Blue at coronal and middle third.
3. Kedo SG Blue (controlled memory files) showed considerably good results compared to Wave One Gold.
4. Even though Ni-Ti rotary files have many advantages over hand files, Ni-Ti files can induce variable degree of dentinal defects during root canal preparation.

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