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Original Article

Evaluation of the incidence of apical crack formation after different root canal obturation techniques using a stereomicroscope. (An In vitro study)

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ABSTRACT

The present study evaluated the incidence of apical cracks after root canal obturation using lateral and vertical compaction techniques. A total of 20 human mandibular single rooted premolars were used and instrumentation was done using EdgeEndo files up to 40 taper 4%. Samples were randomly divided into two groups (n = 10) according to the obturation technique used either lateral or warm vertical compaction using Totalfill bioceramic sealer. For every specimen, four digital photographs of the resected apical root surface were captured: baseline, immediately following preparation, just after filling, and after 14 days. then the images were examined for the presence of any new apical cracks. Mann-Whitney U test was used to compare between the two groups. Friedman's test followed by Dunn's test was used to study the changes within each group**.** After instrumentation, there was no statistically significant difference between incidence of cracks in the two groups (P-value = 1). Both groups showed the same incidence of cracks (80%). After obturation as well as after 14 days; there was no statistically significant difference between incidence of cracks in the two groups (P-value = 0.474) and (P-value = 0.474), respectively. Warm vertical compaction group showed higher incidence of cracks

than lateral condensation group (100% and 80%, respectively). Warm vertical compaction technique is 2.25 folds prone to crack compared to lateral condensation technique. Rather than the kind of obturation technique, apical root cracks were found to be more linked with root canal instrumentation.

Keywords: Bioceramic sealer; Dentinal cracks; Lateral condensation; Warm vertical compaction.

1-Introduction

The success of endodontic treatment, in part, relies on the effectiveness of the obturation in preventing future bacterial invasion.To ensure complete filling, root canal sealers are combined with a core material, such as gutta-percha, which can be utilized in cold lateral compaction or warm technique. Cold lateral compaction has been employed for decades and has demonstrated clinical efficacy. However, this technique may lead to cracks on the root canal walls that could potentially develop into fractures with severe clinical repercussions. Despite this concern, many practitioners still use this method due to its simplicity, lack of need for specialized or costly tools, and perceived safety in controlling the apical extension of the filling [1,2,3].

When warm vertical compaction technology is applied well, it was hypothesised that, dentinal defects are not likely to occur. Warm vertical compaction exhibits superior adaptation of the filling material to the canal walls than lateral compaction, notwithstanding the possibility that hydraulic forces may exert pressure against the root canal walls, creating a wedging effect. On the other hand, it can cause filling material to be extruded into the periapical tissues. [4].

The variables of spreader load, canal flare, root and canal dimensions, rate of strain, and spreader design have been found to be significant factors to vertical root fracture by analysis of the lateral condensation forces. One of the undesirable side effects of root canal treatment, which frequently necessitates tooth extraction, is vertical root fracture. A microcrack or craze line that spreads with repetitive stress application from occlusal loading may be the cause of the root fracture. [5].

Advancements in root canal hydraulic sealers continue to emerge, focusing on achieving optimal sealing properties and incorporating bioactive properties. The shift in contemporary endodontic practice leans towards utilizing novel bioceramic sealers, such as TotalFill BC Sealer (FKG Dentaire, Switzerland), a ready-to-use, injectable, premixed bioceramic endodontic sealer. For this hydrophilic sealer to start and complete its setting reaction, dentinal tubule moisture is necessary. Its biological properties are influenced by its chemical composition and the sequential processes of hydration, precipitation of calcium phosphate, and hydroxyapatite formation [6, 7], fostering a direct bond between the dentin and the material [8]. Additionally, the sealer's nanoparticle size allows for easy penetration into canal irregularities and dentinal tubules. The TotalFill BC Sealer has been further developed into TotalFill BC Sealer HiFlow (FKG Dentaire, Switzerland) as a suitable calcium silicate-based sealer for warm canal filling techniques. As per the manufacturer, this new sealer exhibits a lower viscosity when heated and enhanced radiopacity compared to its predecessor.

Thus, the aim of this study was to compare the incidence of crack formation during different root canal obturation techniques. The null hypothesis tested was that there is no significant difference in the crack incidence using both cold lateral condensation or warm vertical compaction.

2. Experimental

Ethical regulation:

The research proposal was granted an ethical approval by the Research Ethical Committee (REC) at the Faculty of Dentistry, Minia University (Registration no. 314/2018).

Sample size calculation

This power analysis used crack initiation after instrumentation as the primary outcome. Based upon the results of Adorno CG et al (2013)[9], the calculated effect size (w) was 0.59. Using alpha (α) level of (5%) and Beta (β) level of (20%) i.e. power = (80%); the minimum estimated sample size was a total of 20 samples (10 samples per group). Sample size calculation was performed using G*Power Version 3.1.9.2.

Sample Selection:

Twenty freshly extracted human lower premolars were examined using 2.5X magnification Loupes (Ergovision, China) to exclude any teeth with pre-existing root fractures or cracks. Preoperative radiographs were captured in the mesiodistal and buccolingual directions to confirm the presence of a single canal and the absence of any exclusion criteria which included teeth that demonstrated calcification or immature teeth, previous root canal treatment or presence of old restorations, teeth with signs of resorption (internal or external resorption), as well as those that might have hair line fractures. Teeth were cleaned from soft tissue attachments and immersed in sodium hypochlorite solution for thirty minutes followed by washing and immersion in 0.1% thymol up till the completion of the sample size and the beginning of experiment, but no longer than 30 days following tooth extraction.

Grouping of samples:

The selected samples were randomly divided into two equal groups according to the obturation technique used during filling of root canals:

- Group A: Lateral compaction technique was used (n = 10).
- Group B: Warm vertical compaction technique was used (n = 10).

Preparation of the samples:

Decoronization of all teeth were done to a standardized length of 17 mm using a low-speed saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA) under water cooling. All samples were mounted in cylindrical acrylic blocks (height 16 mm and diameter 20 mm) to accommodate the whole root length for standardization during cutting. The apical 1 mm of the apex was ground perpendicular to the long axis of the tooth followed by surface polishing disc (Sof-Lex, 3M ESPE, USA). All the blocks were grouped and numbered with letter codes.

Mechanical preparation

All roots from the resected apical surface were imaged using digital camera (EOS 650D, Canon, Japan) held on Light stereomicroscope (Olympus BX43; Olympus Co., Tokyo, Japan) at magnification 70x as a control image before endodontic steps to ensure no cracks were present in any of the samples. A size 10 K-file (MicroMega, Besançon, France) was inserted into the canal

until it was visible at the apical foramen, the working length was determined subtracting 1 mm from this measurement. All roots were mechanically prepared by EdgeEndo file system starting from 17\04, 25\04, 30\04, 35\04 and 40\04 mounted on an endodontic motor (Traus, Seashin, Korea) following the manufacturer instructions at 350 rpm speed and torque 2.5 N/cm.

Irrigation protocol:

After each instrument used, the canal was irrigated with 5ml of 2.5% sodium hypochlorite (NaOCl; CHLORAXID 5,25% EXTRA, Cerkamed, Pawłowski, Poland) by using a 30-gauge needle (NaviTip, Ultradent, South Jordan, UT, USA) adapted to a disposable plastic syringe. After the last instrument was used, each canal was irrigated with 5ml of 2.5% NaOCl, 5ml saline followed by 5 mL of 17% EDTA (Cerkamed, Pawłowski, Poland) and a final flush with 5 mL saline and dried with paper points (Dentsply Sirona, York, Pennsylvania).

Root canal obturation:

All roots were obturated using gutta-percha and bioceramic root canal sealer (TotalFill HiFlow, FKG Dentaire Co. Dental Products, Switzerland).

Group A (n = 10): Totalfill sealer was provided in an injectable premixed syringe with single use intracanal tips. The sealer was injected into the coronal one third of the canal by a disposable intracanal tip. 40/0.04 master cones (Dentsply Maillefer, Ballaigues, Switzerland) were coated with sealer and placed into the canal to the WL. To ensure complete coating of the canal walls with the sealer. The cone was then removed and reloaded with the sealer and permanently seated into the canal. Lateral condensation was done using finger spreader size 30 adding accessory cones size 25. Excess gutta-percha was removed using hot instrument and vertically compacted with a plugger.

Group B (n = 10): Samples were sealed with warm vertical compaction technique according to the manufacturer's instructions using EQV obturation device (Meta Biomed, Republic of Korea) and TotalFill HiFlow (FKG Dentaire Co. Dental Products, Switzerland).

Mesio-distal and buccolingual radiographs verified the quality of the root canal

obturation. New specimens were substituted for those with inadequate root canal filling. A temporary filling material (Cavit-G, 3M ESPE, USA) was used to seal the coronal end. One operator carried out every procedure. To guarantee complete sealer setting, the teeth were kept for 14 days at 37°C and 100% humidity after obturation.

Stereomicroscopic examination

Sections were captured at 70x magnification using a digital camera (EOS 650D, Canon, Japan) attached to a stereomicroscope (Olympus BX43; Olympus Co., Tokyo, Japan). A total of 4 images for the resected apical surface were documented for each specimen (baseline, after preparation, immediately after obturation, and 14 days after filling/ storage). The photos were examined and compared to the baseline image to see whether any new cracks were present. To minimize inter-operator variability, the same skilled operator prepared each root canal; two additional examiners, who were blind to the research groups, carried out the image analysis.

3-Results and Discussion

Qualitative data were presented as frequencies and percentages. Fisher's Exact test was used for comparisons between the two groups. Friedman's test was used to study the changes within each group. Quantitative data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed non-normal (non-parametric) distribution. Quantitative data were presented as median, range, mean and standard deviation (SD) values. Mann-Whitney U test was used to compare between the two groups. Friedman's test followed by Dunn's test was used to study the changes within each group. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

No statistically significant difference between incidence of crack formation in the two groups were found after instrumentation, both groups showed an incidence of 80% of specimens of crack formation. After obturation as well as after 14 days, Warm vertical compaction group showed higher incidence of cracks than lateral condensation group (100% and 80%, respectively), however there was no statistically significant difference between incidence of cracks in the two groups (P-value = 0.474, Effect size = 2.25) and (P-value = 0.474, Effect size = 2.25) respectively (Figure1, 2). Warm vertical compaction technique is 2.25 folds prone to crack

compared to lateral condensation technique.

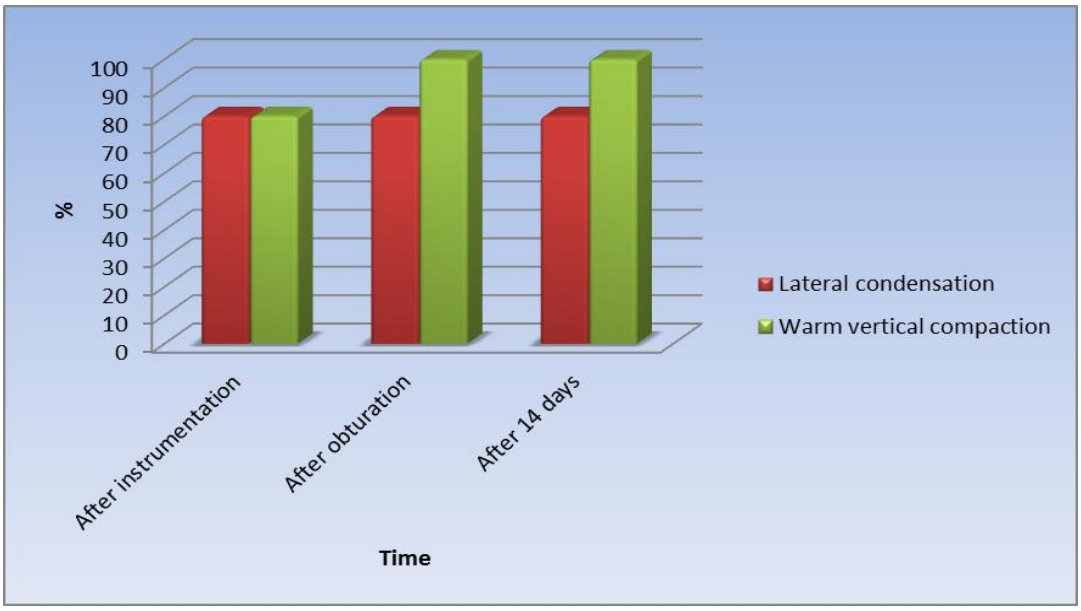

Figure 1: Bar chart representing incidence of cracks in the two groups

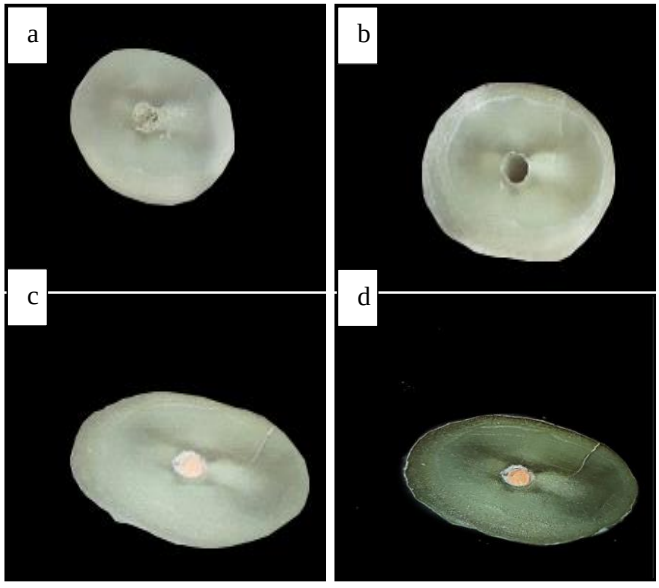

Figure 2: Stereomicroscope cross sectional images (X70) of roots of mandibular premolars. (A) baseline image, (B) after instrumentation, (C) after obturation, (D) after 14 days storage.

The primary objective of effective root canal treatment is the comprehensive eradication of intracanal bacterial populations. To achieve this, chemo-mechanical preparation is often employed, involving various instrumentation techniques and irrigation protocols. Despite its efficacy in reducing microbial inhabitants, root canal preparation may inadvertently weaken the remaining tooth structure, potentially causing micro-cracks and crack lines. When subjected to stress, such as from occlusal forces, restorative procedures, or endodontic interventions, these micro-cracks and crack lines can propagate, resulting in oblique root fractures. Consequently, this may lead to the failure of endodontic treatment [10,11,12].

Regarding the present study extracted mandibular premolar were used [13]. In a trial to achieve standardization of the samples: extraction time, storing conditions, buccolingual and mesiodistal dimensions were measured so that the selected samples were standardized regarding the remaining dentin thickness as these factors might affect results [14]. Samples were embedded in acrylic resin blocks for easy handling and manipulation and to ensure perpendicular cutting to the long axis of the tooth.

All teeth were decoronated till 17 mm using a double-sided diamond coated disc under water coolant, eliminate any variables in access cavity preparations and to facilitate the procedures [15].

In the present study, after grounding all teeth apex at 1 mm of the apex perpendicular to the long axis of the tooth to eliminate any anatomical dentin defects, apical delta or apical deviations using a low-speed saw, a baseline images were taken using a digital camera attached to a stereomicroscope prior to mechanical preparation to guarantee that the chosen samples are free of cracks following grounding and to support the hypothesis that any dentinal defects found as a result occurred during the instrumentation or obturation operations [13].

Özyürek et al 2017 [10] used 1% NaOCl solution was to lessen the detrimental effects of NaOCl on the microstructure of dentin, however in the current study, 2.5% NaOCL were preferred to simulate clinical situations. A final flush of saline was used in order to neutralize the effect of irrigating solutions. EDTA, being a chelator is known to interfere with the formation of calcium silicate hydrate gel which is important for chemical bonding to the root canal dentin walls [16].

The Total Fill BC sealer has been recently introduced in the market as a premixed and injectable sealer, exhibiting excellent radiopaque, zero-shrinkage, insoluble characteristics [17].

Totalfill bioceramic sealer is hydrophilic in nature using moisture from the dentinal tubules to initiate and complete its setting reaction and has a delayed setting time, allowing hydration and swelling to fill any voids. The impact of this physical property on the incidence of crack formation and/or the propagation of cracks caused by mechanical preparation has not been investigated yet. The last image was captured after 14 days to ensure complete setting of the Totalfil BC, Bayram et al [15] reported that BC Sealer requires at least 168 hours before being completely set under different humidity conditions.

Since cold lateral compaction is safe, economical, and allows for filling length control, it is likely the most widely taught and utilized obturation technique worldwide. [18], However the wedging forces of the spreader during lateral condensation creates stresses in the root during obturation, which could lead to an increase in cracks incidence and propagation [18]. Vertical compaction of warm gutta percha combines reasonable ease with maximal effectiveness in consistently sealing simple root canals and complex root canal systems coronal and apically also sealing of accessory canals [19].

The result of this study demonstrated that after instrumentation there was no statistically significant difference between the incidence of crack formation in the two groups. Both lateral condensation and warm vertical compaction showed the same incidence of cracks which were higher than base line. It has already been reported previously that there are craze lines and incomplete cracks after instrumentation. Adorno et al. [9] found that in the apical third, root canal procedures have the potential to initiate and propagate cracks, but that filling techniques have no significant effect on crack initiation. The incidence of dentinal cracks or fracture was observed to be considerably influenced by root canal instrumentation, according to Kumaran et al. [20].

They found no significant difference between lateral compaction with Gutta-percha and warm vertical technique in crack incidence but yields noticeably more defects than passive Gutta-percha obturation. When an external force, like root canal filling procedure, is applied, these craks may become high stress concentration locations from which the fracture may eventually progress to the root canal surface.

After obturation as well as after 14 days; there was no statistically significant difference between incidence of cracks in the two groups, however, warm vertical compaction group showed higher incidence of cracks than lateral condensation group.

This is consistent with the findings of Onnink et al. [21], who discovered that there was no statistically significant difference in the incidence of stained fracture between the three obturation groups (cold lateral condensation, thermoplasticized central cone, and injectable gutta-percha) and the group that received only canal preparation. Using the lateral compaction or continuous wave approach, Shemesh et al. [13] reported no difference in the occurrence of defect between roots filled with AH26 and gutta-percha. The thickness of the remaining dentine or the level of the root did not correlate with the appearance of the cracks .

De-Deus et al. [22] reported that in lower molars using micro-computed tomographic analysis, root canal filling procedures using GuttaCore (GC), cold lateral compaction (CLC), and warm vertical compaction (WVC) techniques did not encourage the development of new dentinal microcracks because there were insufficient factors to start cracks.

It is unknown if the forces generated by this expansion could be strong enough to contribute to the incidence or propagation of cracks because their potential magnitude has not been previously investigated. Whereas dentine cracks get blunted and need greater loads to progress, cyclic stressing is necessary for crack formation [23, 24, 25]. Cyclic loading will cause the fracture to progress by allowing it to alternately sharpen and blunt. Stress concentration, which concentrates strain energy on the subsequent vulnerable bond during fracture propagation, is determined by how acute the crack tip is. [26].

4. Conclusion

Rather than the kind of obturation technique, apical root cracks were found to be more linked with root canal instrumentation.

- **Conflict of Interest**

The authors deny any conflicts of interest related to this study.

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