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Review

Formation and Effect of Dentinal Microcracks After Root Canal Treatment

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Abstract

Many potential causes of root fracture have been put forth over the decades, such as theories that the fracture might begin with dentinal microcracks (DM) brought on by dentinal dehydration, post-insertion corrosion, spreader form, or strong movements utilized while filling processes. In the recent times, scientists have found that a sizable proportion of preexisting dentinal defects on the roots to be present. These problems are though too likely to be brought on by high extraction pressures and/or the way the teeth were stored. The limits of the standard methodologies are undoubtedly vulnerable to systematic analytical inaccuracies, making them far from an optimal experimental model, according to scientific rationale underlying this ambiguous scenario. It has also been shown that dentin moisture affects the biomechanical response of radicular dentin to root canal preparation, specimen storage circumstances are another issue with investigations on dentinal microcracks development. Instrumenting with manual, reciprocating, or rotary NiTi tools does not produce remnant microstrain accumulation in hydrated roots.

Keywords: *dentinal microcracks, root canal preparation, root canal treatment, biomechanical response*

Introduction

The incidence of root breakage in healthy teeth or those that have undergone endodontic treatment or restoration has grown significantly in importance in endodontics in the past few years (1-3). One of the chief reasons of loss of teeth today and described as a serious clinical outcome is root fracture (4, 5). Many potential causes of root fracture have been put forth over the decades, such as theories that the fracture might begin with dentinal microcracks (DM) brought on by dentinal dehydration, post-insertion corrosion, spreader form, or strong movements utilized while filling processes (6-8). Recently, Bier et al. (9) and Shemesh et al. (10) found a correlation between root canal treatment (RCT) using motor-driven nickel-titanium (NiTi) tools and the development of DM. It is not surprising that this occurrence has grown in significance in the field of endodontic dentistry given that mechanical preparation of the root canal (RC) has evolved as the standard for RC shaping (9-16).

Generally, in the majority of ex vivo research on DM formation, the sample is sectioned and then the visible dentinal layer is observed postoperatively through optical microscopy (9–15) (9-15). The destructive approach of the technique, the two-dimensionality of the view, inability to inspect full-tooth range, and the dearth of longitudinal follow-up, as it does not permit the evaluation of the unprepared specimen, are some major drawbacks of this methodology that lower its reliability. As a result, it is doubtful that the findings of the majority of these studies—where cracks were found in more than 40% of the samples —would accurately reflect the actual situation (16). The limits of the standard methodologies are undoubtedly vulnerable to systematic analytical inaccuracies, making them far from an optimal experimental model, according to scientific rationale underlying this ambiguous scenario. DM production is now well understood thanks to recent developments in imaging technology, such as the use of micro-computed tomography (micro-CT) in dental studies. Every tooth functions as its own control, scores of slices can be examined per sample, and the extent of the flaws can be monitored because Micro-CT has high accuracy and a nondestructive method that permits the longitudinal evaluation of the samples across the experimental processes (17-20). De Deus et al. demonstrated a definite absence of a causative association between the formation of DM and RC preparation with rotary and reciprocating devices utilizing this technique (20). Other investigations employing similar methods later supported this conclusion. (18, 19). Nonetheless, scientists noted that a sizable proportion of preexisting flaws on the roots were present. These problems were likely brought on by high extraction pressures and/or the way the teeth were stored. As a result, these circumstances also do not support an experimental model that is nearly perfect. Thus, despite the substantial amount of data that has been gathered over the past 30 years, important issues remain unresolved about a number of features of crack initiation and endodontic operations. The viscoelastic qualities of the attachment apparatus would absorb the stresses given to the tooth structure during RC preparation operations, which has lately been proposed as the optimal methodological technique for a thorough study of DM formation (14).

Methodology

This study is based on a comprehensive literature search conducted on December 21, 2022, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the information about formation and effect of dentinal microcracks after root canal treatment. There were no restrictions on date, language, participant age, or type of publication.

Discussion

Nowadays, root sectioning techniques and direct optical microscopic observation form the foundation of the majority of investigations linking mechanical preparation with the occurrence of dentinal faults. Due to conflicting findings on how ProTaper Universal and Reciproc instruments used in rotary and reciprocating activity, correspondingly, affected the radicular dentin and caused dentinal faults, these instruments have been evaluated in several investigations (13, 21-23). In these investigations, preparation with the ProTaper Universal system up to the F2 instrument resulted in an occurrence of DM ranging from 50% (13) to 80% (22, 23), while preparations with the Reciproc R25 tools resulted in cracking in 5% (13) to 65% (21) of the samples. This destructive experimental model has a significant flaw since the frequent occurrence of cracks seen following RC preparation with these devices is far from the truth of the clinical environment. Hence, there are significant

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discrepancies among the experimental models that can reasonably account for this divergence of outcomes. The key results of the root-sectioning research seem to be supported by the utilization of unprepared teeth as controls, but these groups were only able to regulate the mechanical stresses brought on by the mechanical NiTi preparation system per se, ignoring the interaction as well as the cumulative impact of all procedures to which the teeth were subjected, like irrigating with hypochlorite and the sectioning (18-20). In two root-sectioning research (11, 24), it is worth noting that DM has also been documented in the untreated control teeth. The researchers explain that these DM were precipitated by forces induced during extracting the teeth, heavy pressure brought on by occlusal impairment prior to extracting, prior injury, and/or the sectioning operations. It is crucial to keep in mind that since traditional sectioning methods only allow for the assessment of a small number of slices for every tooth, there is a real prospect of overlooking root-related faults, which implies that control samples in these experiments were probably underestimating the existence of pre-treatment DM (18). Since it has lately been shown that dentin moisture affects the biomechanical response of radicular dentin to RC preparation, specimen storage circumstances are another issue with investigations on DM development. Instrumenting with manual, reciprocating, or rotary NiTi tools does not produce remnant microstrain accumulation in hydrated roots (25). The threshold state of the specimen is essential for the validity of the laboratory research on DM formation, given that crack development may persist in root slices also after one month of preservation with no additional load on dentin (26). The optimal containment temperature is not precisely determined by empirical proof, and the influence of various temperatures on biomechanics and biologic behavior is heavily debated (16). On a precise temperature for teeth, there is no international agreement, universal guideline, or tissue banking standard. In recent comments, the American Association of Tissue Banks suggested storing tissue at a setting of 20°C for up to six months and 40°C for extended deep-freeze conservation durations (27). In reality, further research is needed to fully understand and identify the effects of storage time and cooling temperatures on the biomechanic characteristics of teeth. In this investigation, the American Association of Tissue Banks' advised preservation temperature of 20°C and gradual defrosting for imaging and processing operations had no impact on the bone or tooth form (27).

The sides of the RC are subjected to rotary forces when NiTi rotary tools are utilized. As a result, the radicular dentin may develop DM or craze lines. The tip shape, cross-section topology, taper kind (continuous or progressive), pitch (fixed or varying), and flute structure may all have an impact on how severe a fault generation is. The self-adjusting file (SAF) is not a rotary tool; although, it is a NiTi file. It operates by removing dentin from the RC by grinding back and forth. Various NiTi rotary tools cause fractures that may lower the lifespan, and protection against tooth fracture, which are key endodontic goals. Experiments have demonstrated that extreme dentin clearance during obturation with a spreader, post space preparation, and RC operations can result in fracturing of teeth (12). When obturating and retreating techniques were taken into account, Wilcox et al. (28) and Shemesh et al. (10) showed varying degrees of fracture incidences of 40%, 16% to 25%, and 12%, respectively. According to Bier et al. (5), fractures did not happen right away following RC preparations. But 4% to 16% of the cases had craze lines, which could lead to fractures after repeated treatment or after persistent mechanical loads like chewing (28). In this context, NiTi rotary systems used for RC preparation or each subsequent endodontic treatment that comes after, such as retreating and obturating, might result in fractures or craze lines. Numerous ex vivo tests revealed a reduced frequency of microcracks (9, 10). However, Wilcox et al study's (28) and Shemesh et al study's (10, 29) and our findings are in agreement (29). Single-rooted teeth were utilized as samples in the majority of in vitro investigations that evaluated the prevalence of dentinal injury following root canal treatments. Defect rates in the current investigation may therefore also increase as a result of repeated instrumenting of roots (30). According to Kim et al. apex stress and strain intensities while instrumenting were influenced by file form, and these intensities were connected to a rise in dentinal faults and RC deviance (31). Due to the fact that RC obturation and ultimate repair might start cracking or lead them to spread from certain faults, these in consequence were linked to a higher propensity to vertical radicular fracture. Moreover, rotary NiTi files require many more spins in the RC to finish a preparation than HF do (32). This alone could have a role in the development of dentinal faults. The torsion and bends (33), cyclical fatigue (34), flexibility (35), and

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other material characteristics of NiTi tools have been examined and contrasted. The physical properties of rotary NiTi tools differ from one another. According to Arbab-Chirani et al. (33), Mtwo (Sweden & Martina, Padova, Italy) is more flexible than ProTaper (PT) F1 and HS and has a lower torque and bending force than those two materials. Mtwo is roughly twice as flexible as HS and three times as flexible as PT. The biggest number of defects in this investigation may have been caused by the HS's comparatively low flexibility. Additionally, the increasing taper of the PT F1 may account for its greater stiffness by causing a bigger cross-section (33). All NiTi tools examined in the current investigation shared a triangle cross-section topology with various designs in every category. The four NiTi rotary file groups did not significantly vary in terms of fault occurrence. The identical cross-section design of the examined NiTi tools may be the cause of these similar outcomes. The RS group had the fewest defects overall. There have not been any prior studies on this file system. But the asymmetrical cross-section and longer cutting area in the coronal zone, which promotes tool flexibility, according to the makers, RS places less stress on the tool (36). Forty percent of the twisted file (TF) group's defects were found. The TF demonstrated the least opposition to recurrent torsional pressures in a research that assessed the torsional opposition of NiTi files.

Applying steady, careful compression to the RC walls while the SAF file smoothly collapses into the RC before attempting to restore its former proportions. This enables for consistent dentin reduction around the complete RC cross-section (37). It might be the cause of the experimental specimens' lack of flaws brought on by SAF. In that they found no defects in the hand file (HF) group, their investigation concurs with Bier et al. (9). Additionally, research using a spreader to test fractures has produced conflicting results; in one study, HFs were discovered to be the most resilient materials (38). Nevertheless, they were discovered to be the least resistive in another investigation (39). Even though it sheds light on the smallest force required to fracture a root, this does not replicate clinical situations (28). Furthermore, it has been claimed that the amount of dentin removed from the RCs overall with NiTi rotary devices was substantially higher than with hand files, implicating increased issues that may impact the prognostic stability of the teeth, but the effectiveness of HFs in cleaning and preparing RCs is still debatable (40). It is remarkable that SAF made cross sections that resembled the canal's original shape more frequently than NiTi devices, which produced circular cross sections in the samples analyzed. According to Metzger et al. (41), the majority of rotary file systems would locate the canal's widest point and gradually enlarge it with a number of files of progressively larger diameters to create a canal with a circular cross section. The entire original RC may be incorporated into the preparation if the RC is reasonably narrow. Nevertheless, this method of preparation may expose unaccessed recesses, primarily buccally or lingually to the machined component of the RC, if the RC is flat, elliptical, teardrop-shaped, or merely wide (41). Due to the lattice's collapsible and expanding nature, the SAF file touches the inner RC wall at all locations. Since this RC inhibits the production of pressure, this trait may not induce any DM in the dentin. Furthermore, the lattice threads' surface is minimally abrasive, allowing for the removal of dentin via back-and-forth grinding as opposed to cutting with the NiTi rotary files' spinning blade (20). Such drilling by the rotary files may thin the residual dentin on the interior of the curve to the point where it raises the likelihood of vertical radicular fracture or even leads to a strip perforation (42). We can draw the conclusion that NiTi devices frequently cause varying degrees of dentinal damage during root canal preparation, even if this in vitro investigation did not accurately represent clinical circumstances. The SAF file and manual instrumentation, in contrast hand, provide favorable outcomes with no microcrack faults.

Conclusion

Even though it is obvious that the method used to prepare the RC is likely irrelevant to the development of DMs, it is still unclear how different restorative techniques used following endodontic therapy would influence the emergence of DMs. Additionally, thorough reporting of the adherence to stringent guidelines from dental extraction to ultimate analysis must be obtained and publicized. Current findings suggest that when properly applied, the different RC preparation methods taken will not harm the tooth structure.

Disclosure

Conflict of interest

There is no conflict of interest

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Ethical consideration

Non applicable

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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