THE CONSEQUENCES OF PERI CERVICAL DENTIN PRESERVATION ON MANDIBULAR MOLAR CRACK EXPANSION

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Abstract

Introduction: The purpose of the research was to use the finite element approach to examine the impact of peri- cervical dentin conservation during root canal therapy on the longitudinal development of cracks. **Methods**: Two mandibular teeth that were manufactured in 3D underwent a mock root canal procedure. Two test populations of teeth were created: Group 1: Rotary files from a Protaper Gold (PTG) instrument were used. Group 2 was equipped with TruNatomy. At the level of the CEJ, every entrance was repaired with composite to the occlusal surface. To build 3-D models and stereolithographic reconstructions for Finite Element Analysis, the two teeth were digitally obtained through a high-resolution micro-computed tomography scan. The distal marginal ridge was the starting point of a crack that was mimicked, and it extended horizontally to the distal occlusal cavosurface and apically 2 mm above the CEJ. A 247-newton weight was applied to each model in order to simulate the strain put on the mouth during mastication. **Results:** The crack began to spread in both groups at about 40,000 mastication cycles. At 60,218,000 mastication cycles, Group 1, which was equipped with a Protaper Gold equipment, experienced crack expansion of 0.5mm. Group 2 had 0.5mm of crack propagation at 10,042,000 cycles and was equipped with TruNatomy. **Conclusions:** Given the constraints of this investigation, it can be said that mandibular molars instrumented with PTG rather than TruNatomy experienced reduced fracture propagation. About 40,000 mastications in, the simulated crack began to spread in both PTG and TruNatomy.

Keywords: Pericervical Dentin, cavosurface, RCT, Crack Propagation

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1. Introduction

Since the COVID-19 outbreak started, dental professionals have seen a rise in the number of patients with fractured teeth. In fact, a recent study found that the incidence of broken teeth rose throughout the COVID-19 pandemic's initial breakout and a year afterwards (1). A "cracked tooth epidemic" is present, according to a 2013 research that indicated a high prevalence of cracked teeth even before the pandemic (2). Whereas teeth may endure stresses of 700N or more (3), cracks frequently occur, leading to cracked teeth. According to one research, 66.1% of patients (2) had at least one fractured molar.

The chance of developing cracks inside the teeth increases with ageing of the dentition (2). According to the size/taper of the root canal preparation, coronal flaring, obturation techniques, and retreatment procedures, iatrogenic variables can also intensify the development of cracks during endodontic operations (4). Historically, peeso eamers, successively tapered file systems, or gates glidden burs have been used to flare the corona. Nevertheless, coronal flaring can lead to the loss of peri-cervical dentin (PCD), a vital structural element. Apical and coronal measurements of the peri-cervical dentin to the crestal bone are around 4 mm. The endodontic access cavity's preparation method and the shape and taper of the endodontic rotary files have changed as a result of PCD preservation.

On the market, there are a variety of endodontic file systems with various cross sections, metallurgy, and taper. For example, the maximum flute diameter (MFD) of the variable taper of the ProTaper Gold (PTG) System (Dentsply Tulsa Dental Specialties, Tulsa, OK) is 1.2 mm. To preserve dentin, however, file systems with noticeably lower MFDs have been made available on the market. One such system has an MFD of 0.8mm and moulds root canal systems to a regressively tapered preparation. It is called TruNatomy (TRN, Dentsply Sirona). The null hypothesis stated that after root canal instrumentation with various tapered rotary files, leftover PCD had no effect on crack propagation in mandibular molars.

Finite Elemental Analysis (FEA) has been used in numerous investigations to assess the stress concentrations using various equipment procedures (3,5,6). Although a different FEA analysis found that coronal canal flaring has no impact on tooth integrity, Smoljan et al.'s study found that preservation of PCD may boost a tooth's resistance to fracture (7). Although there is a large body of research examining stress concentrations, the longitudinal propagation of cracks has received less attention. The impact of the composite resin core level and periodontal pocket depth on stress distribution and crack propagation in endodontically treated teeth have been studied using the Extended Finite Element Method (XFEM) (8). The aim of this study was to investigate the effect of PCD conservation during root canal treatment on the longitudinal propagation of cracks, utilizing the extended finite element method.

2. Methodology

In this investigation, two identical Endo 3DP mandibular plastic molars (tooth #19) from Acadental in Lenexa, Kansas, were employed. The same endodontic approach was used on both teeth. The ModuPRO manikin (Acadental) and carriers for the ModuPRO teeth were then attached, respectively. Both teeth were able to glide up to a 15 K-file , and the working length measurement was established with a radiograph that was taken 0.5 mm below the radiographic apex. According to the manufacturer's protocol, Group 1 was instrumented with ProTaper Gold to F2 (25/0.08v) in the mesial canals and F3 (30/0.09v) in the distal canals.

Following to the manufacturer's instructions, Group 2 was instrumented with the TruNatomy system to a primary

26/0.04v in the mesial canals and 36/0.03v in the distal canals. After instrumentation, the canals underwent saline irrigation, paper point drying, and obturation with gutta-percha, warm vertical compaction, and EndoSequence BC Sealer. The access restoration was completed using composite after obturation. Each technique was carried out on a manikin with a microscope to replicate clinical care. All teeth were digitalized using a high-resolution micro-computed tomography scan following the RCT operations were finished in order to provide 3-D models and stereolithographic reconstructions for FEA.

Micro CT and Meshing

Utilising a GOM computed tomographic scanner, GOM Inspect software, and parameters including 25 mmol/L voxel size, 150 kV target X-ray voltage, 40 W target power, exposure length of 1500 ms, and 750 exposures, a micro-CT scan and stereolithographic reconstruction of teeth were performed. The fracture growth behaviour of a root canal treated tooth exposed to a mastication force of 60 MPa applied to four circular areas with a total area of about 4 mm2 (247 Newtons) is studied numerically using the Finite Element Method and the commercial software ANSYS. The Paris Law model is used to evaluate the crack growth. Da dN describes the relationship between the crack growth rate (da) and the induced range of dN = C (k)m.

The stress intensity factor (Δk) where, a is the crack length, N is the number of cycles, C andm are material properties and k the stress intensity factor.

Geometry Building

The outermost layer of the molar, the inside pulp cavity, various crown/canal preparation shapes, and the bulk of the filling material were generated as 3D Computer-aided Design (CAD) models. A micro-CT acquisition employing a GOM computed tomographic scanner was used to produce the major segmentation data for the molar shape in both its intact and prepared states. For additional polygon decimation, smoothening, and refinement on Geomagic software (3D systems), the gathered data was combined into STL files. Using Solidworks software, manual patches were created, NURBS surfaces were fitted, and the data was transferred in IGES format for further modification.

The intended adjustments included defining the boundaries between the dentine and enamel bodies, using Boolean operations to hollow out the dentine body using inner surfaces that were a representation of different crown/canal preparations, virtually developing and establishing the crack in the crown, building the composite filling for the treatment scenarios to be addressed, in-context reconstructing the periodontal ligament with a uniform thickness of 0.2mm, and intuitively creating a mandibular. The crack was simulated at the distal marginal ridge extending horizontally to the distal occlusal cavo-surface margin and apically 2mm above the CEJ. The valuesfor the structural properties of the materials incorporated into the study were from previously published data (5–7,9,10).

3. Results

The outcomes showed that the simulated crack extended over the number of mastication cycles. The application of 247 N of force distributed equally via the four contact locations was replicated as each mastication cycle as a period in a sinusoidal cycle with a constant amplitude. The split in both groups began to spread at about 40,000 mastication cycles. At 60,218,000 mastication cycles, Group 1 (instrumented with Protaper Gold) experienced fracture propagation of 0.5 mm (Figs. 1, 2, 3, 4). The TruNatomy-instrumented Group 2 had fracture propagation of 0.5 mm at 10,042,000 cycles (Figs. 2, 4). The computer utilised in the research ran through 60,461,000 cycles before it ran out of processing power and was unable to provide any more data.

Figure 1: Group 1 crack propagation in mm over number of mastication cycles.

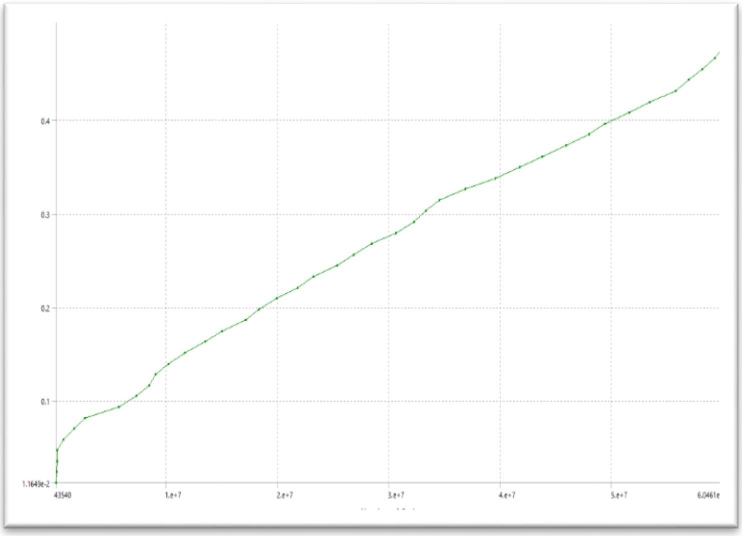


Figure 2: Group 2 crack propagation in mm over number of mastication cycles.

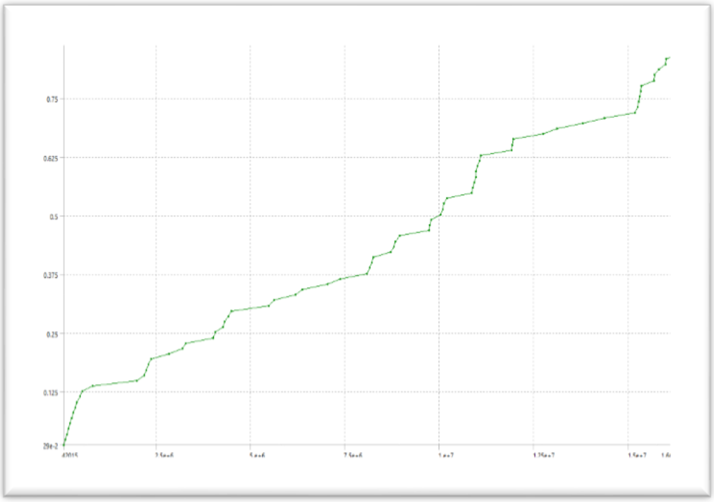


Figure 3 : 3D visualization of group 1 Crack propagation

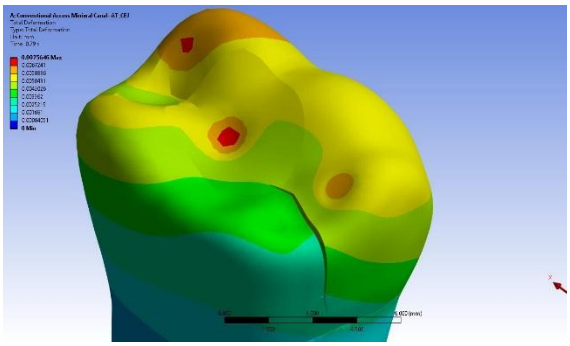
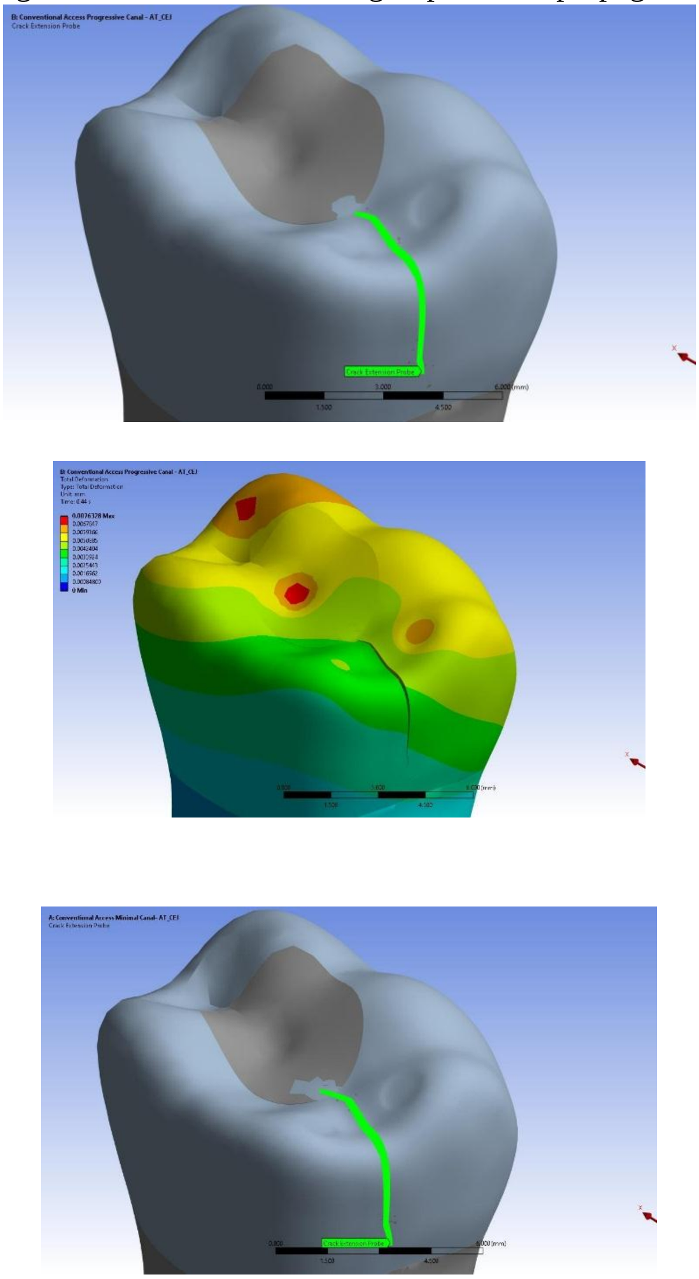


Figure 4: 3D visualization of group 2 Crack propagation



4. Discussion

There are several FEA research in dentistry, nevertheless their practical applicability is debatable because of their limitations. Using a more accurate 3D model and occlusal load simulation, the present research aimed to get around some of the drawbacks of FEA investigations. Since the mandibular molar is the tooth that requires endodontic treatment the most frequently (7,11,12), it was chosen for the simulation. To replicate a true patient situation, the tooth was positioned in a lab mannequin/typodont, instrumented with rotary files, obturated, and repaired. To mimic clinical occlusal interactions, a 4-point contact method similar to that in Okeson's textbook was adopted. Last but not least, 250 N of cyclic stress was dispersed between the 4 contact points to simulate the strain experienced during oral mastication.(13,14).

For assessing stress and crack propagation in computer-generated models, finite element analysis (FEA) has been shown to be a reliable analytical approach. FEA makes it possible to standardise experimental samples, something that is impossible with in vivo research. In this research, a unique FEA approach was used to analyse the spread of cracks in teeth. The objective of this research was to use the finite element approach to examine how PCD conservation during root canal therapy affected the longitudinal spread of cracks.

Previous studies have examined the impact of PCD removal on fracture resistance, but no previously published investigations have examined the impact of PCD conservation on the longitudinal spread of cracks. On the occlusal surface of the digital tooth model used in this investigation, a crack was reproduced.

The fracture was simulated extending mesiodistally on the model because cracks tend to form most frequently in a mesio-distal direction (15). The distal marginal ridge is where the fracture started, and it ran horizontally to the distal occlusal cavo-surface boundary before stopping 2 mm over the CEJ. In order to determine if the crack propagates to and is apical to the CEJ based on the file system being utilised, the longitudinal extent of the fracture was purposefully constrained to 2 mm above the CEJ, occlusal to the PCD. The results of this research imply that mandibular molars instrumented with PTG will have reduced fracture propagation for the same number of mastication cycles as in comparison with molars instrumented with TruNatomy, hence the null hypothesis was rejected. Multiple investigations have demonstrated that excessive PCD loss can reduce a tooth's ability to withstand fracture (7,9,10), and instrumentation with PTG results in a larger loss of PCD than TruNatomy. Conversely, some research contend that minimally invasive accesses and PCD loss have little effect on a tooth's ability to resist fracture (18–20,37). In the current investigation, more conservative file systems used for root canal instrumentation resulted in a higher rate of crack propagation. This might be explained by a greater degree of rigidity in teeth equipped using TruNatomy, which results from more tooth structure being retained. While there will always be limitations associated with FEA studies, the benefits will continue to grow as scanning and analysis methods are improved in future software updates. Improvements in the software could include a more realistic mastication cycle which simulates Posselt's envelope of motion, adding soft tissue boundaries with physical properties and optimized programming to enable longer FEA cycles for readily available computers. Future FEA studies are needed which utilize updated clinical boundaries and technology to predict the crack propagation of endodontically treated teeth more accurately.

5. Conclusion

Within the constraints of this investigation, it can be inferred that mandibular molars instrumented with PTG had a lower fracture propagation rate than those instrumented with TruNatomy. For both PTG and TruNatomy, the simulated crack started to spread after about 40,000 loading cycles. 0.5mm of crack propagation occurred in the PTG instrumented tooth at 60,218,000 mastication cycles as opposed to 10,042,000 cycles for TruNatomy. The computer utilized in the research ran through 60,461,000 cycles before it ran out of processing power and was unable to provide any more data. It takes a computer with more computing power to simulate several mastication cycles.

6. References

1. Nosrat A, Yu P, Verma P, Dianat O, Wu D, Fouad AF. Was the Coronavirus Disease 2019 Pandemic Associated with an Increased Rate of Cracked Teeth? J Endod. 2022;48(10):1241–7.

2. Hilton T FJ. Cracked Teeth Registry. National Dental PBRN Western RegionalMeeting. 2013
3. Hylander WL. Mandibular function in Galago crassicaudatus and Macaca fascicularis: an in vivo approach to stress analysis of the mandible. J Morphol. 1979;159(2):253–96.
4. Bier CAS, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The Ability of Different Nickel-Titanium Rotary Instruments To Induce Dentinal Damage During Canal Preparation. J Endod. 2009 1;35(2):236–8.
5. Mamoun JS, Napoletano D. Cracked tooth diagnosis and treatment: An alternative paradigm. Eur J Dent. 2015;9(2):293–303.
6. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endod Topics. 2006;13(1):57–83.
7. Clark DJ, Sheets CG, Paquette JM. Definitive diagnosis of early enamel and dentin cracks based on microscopic evaluation. J Esthet Restor Dent. 2003;15(7):391–401.
8. Clark D, Khademi J. Modern Molar Endodontic Access and Directed DentinConservation. Dent Clin North Am. 2010;54(2):249–73.
9. Weiger R, Bartha T, Kalwitzki M, Löst C. A clinical method to determine the optimal apical preparation size. Part I. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2006;102(5):686–91.
10. Clark Dalton B, Orstavik D, Phillips C, Pettiette M, Trope M. Bacterial reductionwith nickel-titanium rotary instrumentation. J Endod. 1998;24(11):763–7.
11. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod. 1999;25(7):506–8.
12. Jeffrey P. Okeson D. Management of temporomandibular disorders and occlusion.8th ed. MOSBY; 2019. 56 p.
13. Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Sinkewiz SL, et al. Occlusal forces during chewing—Influences of biting strength and food consistency. J Prosthet Dent. 1981;46(5):561–7.
14. Silva EJNL, Lima CO de, Barbosa AFA, Lopes RT, Sassone LM, Versiani MA. The Impact of TruNatomy and ProTaper Gold Instruments on the Preservation of the Periradicular Dentin and on the Enlargement of the Apical Canal of Mandibular Molars. J Endod. 2022;48(5):650–8.
15. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. Int Endod J. 2011;44(7):610–25.