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The effects of canal preparation and filling on the incidence of dentinal defects

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Abstract

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Aim To evaluate *ex vivo* the incidence of defects in root dentine before and after root canal preparation and filling.

Methodology Eighty extracted mandibular premolars were divided equally in four groups. Group 1 was left unprepared. All other root canals were prepared using Gates Glidden drills and System GT files up to size-40, 0.06 taper at the working length. Group 2 was not filled while the canals of the other groups were filled with gutta-percha and AH26, either with a master cone and passive insertion of secondary gutta percha points (group 3) or lateral compaction (group 4). Roots were then sectioned horizontally 3, 6, and 9 mm from the apex and observed under a microscope. The presence of dentinal defects (fractures, craze lines or incomplete cracks) was noted and the differences between the groups were analysed with the Fisher's exact test.

Results No defects were observed in the roots with unprepared canals. The overall difference between the groups was significant ($P < 0.05$). Canal preparation alone created significantly more defects than unprepared canals ($P < 0.05$). The total number of defects after lateral compaction was significantly larger than after noncompaction canal filling.

Conclusion Root canal preparation and filling of extracted teeth created dentine defects such as fractures, craze lines and incomplete cracks.

Keywords: craze lines, dentine, obturation, preparation, vertical root fracture.

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Introduction

Vertical root fracture (VRF) is a clinical complication that may be associated with root canal treatment and lead to extraction (Tamse *et al.* 1999). Endodontic procedures might contribute to the development of VRF as well as other localized defects such as craze lines or incomplete cracks in root dentine (Onnink *et al.* 1994, Sathorn *et al.* 2005). These localized defects may have the potential to develop into fractures (Wilcox *et al.* 1997, Shemesh *et al.* 2008) and should therefore be prevented. Several factors may be responsible for the formation of dentinal defects: instrumentation and root filling (Onnink *et al.* 1994), high concentration of hypochlorite (Sim *et al.* 2001), tooth anatomy (Wu *et al.* 2004) and post-placement (Kishen 2006).

Lateral compaction of gutta-percha is widely used to fill the root canal system and was reported previously to be associated with an increased risk of VRF (Meister *et al.* 1980, Wilcox *et al.* 1997). Spreader design and applied forces were suggested as contributing factors to the appearance of VRF during lateral compaction (Pitts *et al.* 1983, Dang & Walton 1989). However, laboratory stress distribution studies consistently conclude that the pressure applied during lateral compaction is insufficient to cause VRF (Dalat & Spångberg 1994,

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Lertchirakarn *et al.* 1999). Thus, it remains unclear whether lateral compaction can cause VRF. As an alternative, several techniques where no compaction forces are used have been proposed and shown to produce an apical seal similar to that of lateral compaction when used in conjunction with dimensionally stable sealers (Dalat & Spångberg 1994, Tidswell *et al.* 1994, Ozok *et al.* 2008).

The purpose of this study was to compare the incidence of fractures and other dentinal defects before and after canal preparation and filling either with lateral compaction of gutta-percha or a technique where no compaction forces were used.

Materials and methods

Eighty extracted mandibular premolar teeth were selected and stored in purified filtered water. Proximal radiographs were taken to verify the presence of a single canal. The clinical crowns of all teeth were removed using an Isomet 11-1180 low-speed saw (Buehler Ltd, Evanston, IL, USA), leaving roots approximately 16 mm in length. All roots were observed under 8× magnifications in a stereomicroscope (Zeiss Stemi SV6; Carl Zeiss, Jena, Germany) to exclude cracks. Twenty root canals were left unprepared (group 1) and the remaining 60 teeth (groups 2, 3 and 4) were subjected to the procedures described below. All roots were kept moist in purified filtered water throughout the experimental procedures in order to prevent dehydration.

Cleaning and shaping

Canal patency was established with a size-20 K-Flexo File (Dentsply Maillefer, Ballaigues, Switzerland). The canal opening was enlarged with Gates Glidden drills 3 (size-90) and 4 (size-110) to a depth of 4 and 3 mm from the coronal orifice respectively. Canal preparation followed with System GT rotary files (Dentsply Maillefer) and a torque-control motor (Technika, Pistoia, Italy) at 300 rpm using the crown-down technique with series 40 and 30 files, ending with a size-40, 0.06 taper instrument to 1 mm short of the apical foramen. Each canal was irrigated with a freshly prepared 2% solution of sodium hypochlorite (NaOCl) between each instrument, using a syringe and a 27-gauge needle. Twelve millilitres of NaOCl solution was used for each root canal. After completion of instrumentation, passive ultrasonic irrigation was performed using an ultrasonic file size-15 (Satelec, Merignac Cedex, France) in order to activate the irrigation solution and clean the canals (van der Sluis *et al.* 2007). After completion of the procedure, canals were rinsed with 2 mL distilled water. The prepared roots were divided into three experimental groups of 20 roots each (groups 2, 3, and 4). Group 2 remained without root filling. Group 3 and 4 were filled with gutta-percha and AH26, using two different techniques according to the protocol described below.

Canal filling

Canals were dried using paper point size-40. AH 26 (Dentsply De trey, Konstanz, Germany) was mixed according to the manufacturer's instructions and introduced into the canal on two occasions, using a lentulo spiral, for 5 s each (Hall *et al.* 1996) rotating at 400 rpm to 1 mm short of the working length. Standardized size-40 gutta-percha cones (Henry Schein, Mexico City, Mexico), with a 0.02 taper, were coated with sealer, and placed into the root canal to the working length. In group 3, two additional size-25 cones were placed to a depth where resistance was met without use of a spreader (Souza *et al.* 2008). Group 4 was sealed with the lateral compaction technique using a size C spreader (D1 diameter 0.3 mm, 0.04 taper) (Dentsply Maillefer) and size-25 standardized gutta-percha cones. The force applied to the spreader was controlled using a digital scale and kept at a maximum of 2 kg. A polyether impression material (President, Coltene, Altstätten, Switzerland) was used around the tooth during the filling procedures in order to mimic the mechanisms of stress distribution. The coronal gutta-percha was removed with a flame-heated plugger (0.5-mm diameter, Dentsply Maillefer), and the impression material was removed. Roots were stored for 1 week at 37 °C and 100% humidity to allow the sealers to set.

Examination of roots

All roots were sectioned horizontally at 3, 6 and 9 mm from the apex with a low-speed saw under water cooling (Leica SP1600, Wetzlar, Germany). Slices were then viewed through a stereomicroscope (Zeiss Stemi SV6; Carl Zeiss) using a cold light source (KL 2500 LCD; Carl Zeiss). Pictures were taken with a camera (Axio cam; Carl Zeiss) at a magnification of X12. The dentine was inspected and defects were noted. Defects were categorized as: 'no defect', 'fracture' and 'all other defects' (Fig. 1). 'No defect' was defined as root dentine

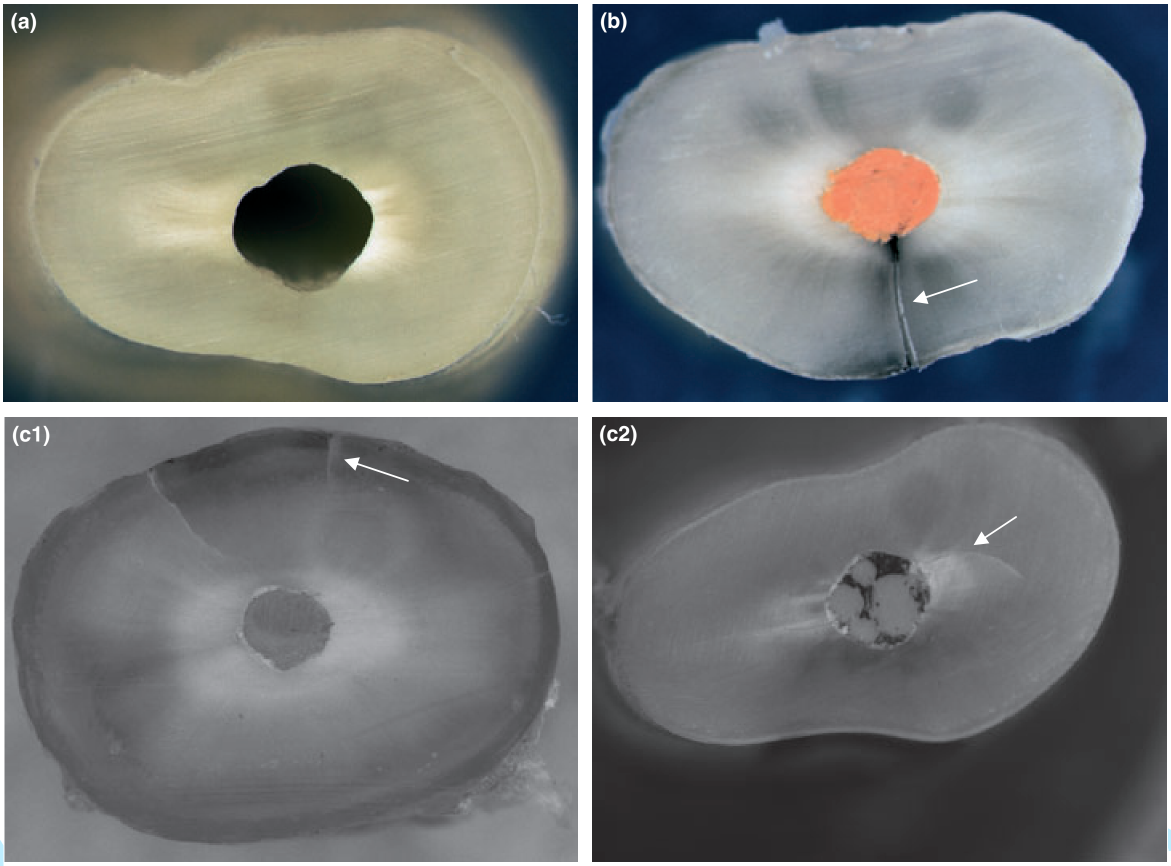

Figure 1 Classification of the different dentinal defects. A – 'no defects', B – 'VRF', C – 'other defects' (C1 = 'craze line', C2 = 'incomplete crack').

devoid of any lines or cracks where both the external surface of the root and the internal root canal wall had no defects (Fig. 1a). 'Fracture' was defined as a line extending from the root canal space to the outer surface of the root (Wilcox *et al.* 1997) (Fig. 1b). 'Other defects' were defined as all other lines observed that did not extend from the root canal to the outer root surface. For example, a craze line – line extending from the outer surface into the dentine that did not reach the canal lumen (Wilcox *et al.* 1997) (Fig. 1.C1), or a partial crack extending from the canal wall into the dentine without reaching the outer surface of the root (Fig. 1.C2).

Statistical analysis

Fisher's exact test was performed to compare the incidence of fractures and other defects between the four groups using the SPSS/PC version 15 (SPSS Inc., Chicago, IL, USA). The level of significance was set at $\alpha = 0.05$.

Results

Figures 2 and 3 summarize the results. The groups were significantly different from each other ($P < 0.05$). The unprepared canals (group 1) had no defects. When considering the overall appearance of defects, the lateral compaction group (group 4) demonstrated significantly more defects than all other groups ($P < 0.05$), while roots with prepared canals (group 2) had significantly more defects than teeth with unprepared canals (group 1) ($P < 0.05$). When considering only fractures, the lateral compaction (group 4) had significantly more defects than the unprepared group (group 1) ($P < 0.05$) but not significantly more than the canal preparation-only group (group 2) ($P > 0.05$).

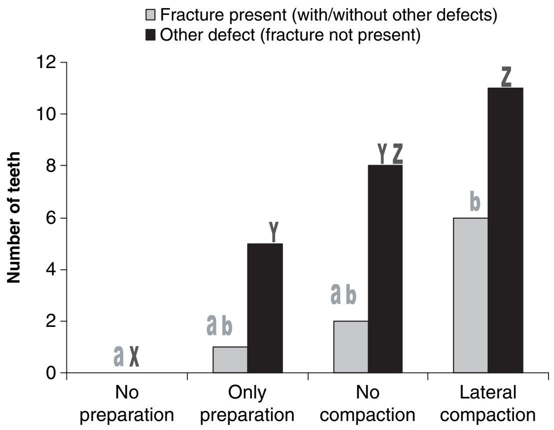

Figure 2 Number of teeth presenting fractures or other defects. Groups with the same letter denote no statistical significance between them ($P = 0.05$).

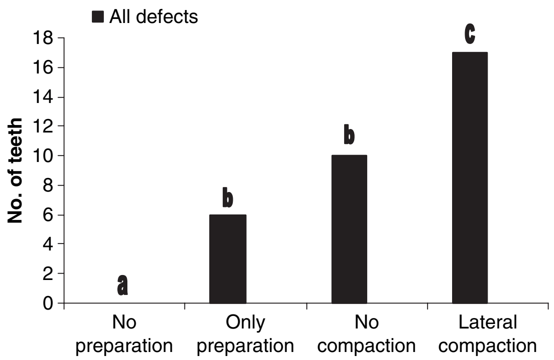

Figure 3 Number of teeth presenting a defect (either VRF or other defects or both). Letters denote statistical resemblance. Groups with the same letter have no statistical difference between them ($P = 0.05$).

Discussion

The sectioning method used in the current study allowed the evaluation of the effect of root canal treatment procedures on the root dentine by direct inspection of the root canal wall, observing not only VRF but also dentinal defects such as craze lines and incomplete cracks. When considering all the defects, the lateral compaction group had significantly more defects than all other groups ($P < 0.05$). Although no definitive conclusion can be made of the clinical consequences of the dentinal defects developed under these *ex vivo* experimental conditions, these findings may contribute to the understanding of long-term clinical observations (Meister *et al.* 1980, Tamse *et al.* 1999) that *ex vivo* methods often could not clarify. It may be hypothesized that craze lines and incomplete cracks might propagate and develop into fractures after completion of endodontic procedures, following additional treatments such as post-space preparation or re-treatment (Wilcox *et al.* 1997), or simply by forces transferred to the root during masticatory function and occlusal loading (Assif *et al.* 2003).

Previous *ex vivo* experiments studying the influence of endodontic procedures on root dentine mainly used one or other of the following methodologies: resistance to fracture, stress distribution measurements or observations of the presence of defects in tooth sections (Obermayr *et al.* 1991, Onnink *et al.* 1994, Saw & Messer 1995, Wilcox *et al.* 1997, Lertchirakarn *et al.* 1999, Mayhew *et al.* 2000, Ribeiro *et al.* 2008).

Resistance to fracture is frequently measured to assess the weakening of the root after different procedures. This method differs from the one used in the current study in that it applies an external force until the root fractures (Ribeiro *et al.* 2008), while in the current experiment, the influence of various procedures on the root canal walls was directly observed and no external forces were applied. Furthermore, resistance to fracture provides no information on the incidence of dentinal defects other than VRF.

Stress distribution studies record stress transmission to dentine during different procedures using strain gauges (Obermayr *et al.* 1991, Saw & Messer 1995, Lertchirakarn *et al.* 1999), or a photoelastic material (Mayhew *et al.* 2000). These studies have shown that the force needed to fracture a root is much higher than that formed during lateral compaction. The current study found relatively few VRF in all groups, confirming this conclusion.

The observation that many of the defects did not connect with the pulp space, and were located in places away from direct contact with intra-canal instruments is baffling. Wilcox *et al.* (1997) speculated that the stresses generated from inside the root canal are transmitted through the root to the surface where they overcome the bonds holding the dentine together. In the current study, craze lines were not seen in unprepared teeth proving that they were caused by the preparation and filling procedures. Onnink *et al.* (1994) claimed that a fracture contained within the dentine in one section could communicate with the canal space in an adjacent section. This supposition was recently supported by nondestructive observations of VRF induced in extracted teeth and viewed with optical coherence tomography (Shemesh *et al.* 2008).

In a series of scans depicting a dentinal defect in one root, an incomplete crack is shown to originate at the root canal wall but later propagates into dentine, demonstrating no communication with the root canal lumen at subsequent sections. In another recent publication, Soros *et al.* (2008) claimed that VRF is mainly a matter of crack propagation and should not be considered as an instant phenomenon.

In the current experiment, the roots were surrounded with an impression material during filling in an attempt to mimic the bony socket that may change the force distribution around the tooth when external forces are used, namely lateral compaction (Lertchirakarn *et al.* 1999). However, the clinical situation is more complex because of the presence of the periodontal ligament that could further influence the distribution of forces. While some studies did not attempt to imitate bone or periodontal ligament (Onnink *et al.* 1994, Ribeiro *et al.* 2008), others have made various attempts to do so. For example, Wilcox *et al.* (1997) used a single layer of aluminium foil and then embedded the teeth in acrylic resin, while Lertchirakarn *et al.* (1999) covered the roots with silicone paste. However, it seems that these attempts are insufficient to mimic the anatomical and biological aspects of tooth structure (Saw & Messer 1995) and could contribute to the introduction of artificial changes in force distribution themselves. Soros *et al.* (2008) stated that elastomeric materials are incapable of withstanding compaction forces in the way that the natural ligament does and that they may collapse under pressure. In agreement with the current findings, they highlight the significance of crack initiation and propagation in the evaluation of VRF formation rather than the actual appearance of a VRF as a result of a specific stress application.

The forces of extraction may also contribute to the observation of incomplete fractures. However, since most of the premolars selected had calculus and staining but no deep carious lesions, an assumption could be made that they were extracted for periodontal reasons with minimal trauma (Onnink *et al.* 1994). This is further confirmed by the finding that unprepared root canals had no defects. The Storage medium used to keep the teeth was purified filtered water. This medium was previously recommended for investigations of human dentine (Strawn *et al.* 1996) as it causes the smallest changes in dentine over time.

System GT instruments have lands, a U-shaped cross section and a noncutting tip. The lands make the instruments passive and prevent canal transportation (Schirrmeister *et al.* 2006). This design increases the contact area with the canal wall as compared to cutting instruments devoid of lands such as the ProTaper system, and might increase friction and torque and thereby fracture risk (Blum *et al.* 1999). This may explain the significantly larger number of defects in the preparation-only group (Fig. 2). It will be interesting to study whether similar defects will be present after preparation with instruments having different designs. Furthermore, Gates Glidden drills were used during the preparation procedure, as they were shown to improve working-safety, avoiding apical transportation and reducing working time (Bergmans *et al.* 2002). They, too, might be a contributing factor to the formation of root defects during preparation, through the action of the burs on dentine, and the excess removal of root structure resulting in weakening of the root (Pilo *et al.* 1998, Kuttler *et al.* 2004).

Little is known on the effects of ultrasonic irrigation on the root canal walls. Further studies should be conducted on the effect of these instruments on root dentine.

Conclusion

Under the conditions of this *ex vivo* study, the use of System GT rotary files and Gates Glidden drills to prepare canals resulted in dentinal defects. The use of a passive compaction technique to fill the canals of extracted teeth significantly reduced the incidence of defects compared to lateral compaction. Clinicians should be aware of the potential damage risks during canal enlargement, preparation and some root filling procedures.

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