Bursting Pressure and Circumferential Root Strains in Ex-vivo Model of Vertical Root Fracture

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Introduction

Endodontic treatment is often required due to pulp pathology caused by dental caries. Treatment is carried out by cleaning and shaping the tooth canal with endodontic instruments that mechanically remove the inner infected layer of root dentine, followed by filling and sealing the root canal. Roots of endodontically treated teeth are prone to cracks or fractures, with vertical root fracture (VRF) as the most common. VRF tends to occur in a bucco-lingual direction, where dentin thickness is greatest. Epidemiologic studies show that the prevalence of VRF is higher in the maxillary second premolar compared to maxillary incisors. Various parameters influence the occurrence of VRF. Obviously, the mechanical properties of the root dentine and root morphology are factors influencing these pathologies. However, assessing the strength properties of the entire root from isolated small specimens is an approach with major interpretative limitations, due to ultrastructural and anatomical variations [1,2]. Testing the strength of the roots as entire anatomic structure or comparing the strength of different roots types were done by destructive methodologies where teeth were loaded up to failure by compressive forces applied to the root by clinical hand spreaders or via a loading machine [3]. Hydrostatic pressure introducing into root canal to create VRF overcome the stress concentrations resulted by such stiff tools [4]. Finite elements models lack the complexity of inhomogeneous and anisotropic root dentine structure. The aim of this study was to quantify the bursting pressure and circumferential strains developing on root dentine surface during VRF and to relate them to morphologic parameters.

Methods

Ten maxillary incisors and 6 maxillary premolars were collected. All teeth were intact and were extracted due to periodontal disease and maintained in moisture until the experiment. Teeth were radiographed and digitally photographed in the bucco-lingual and mesio-distal aspects, before and after failure. Four miniature strain gages, oriented to measure the circumferential strains at the buccal, mesial distal and lingual aspects were bonded at the third apical part of each root. Circular stainless steel plates (d=30mm), with 2 small tubes extending from both surfaces, were fabricated and used to connect the tooth to the pressure system while the other tube was inserted to the root canal cavity. The pressure system was combined of hydraulic piston connected to a loading machine. The tooth was located in a custom made chamber, the 4 strain gages were connected to a strain indicator and the increasing pressure vs. the developed strains were acquired while loading the piston (Fig. 1). After loading and failure of teeth, teeth were sequential sectioning apex to cementoenamel junction CEJ, that is vertically to the longitudinal axes of the root and dentine thickness was measured at all 4 aspects of the root as well as root canal dimensions (Fig. 2).

Results

Characteristic strains vs. pressure data obtained during tooth loading are presented in Fig. 3. All experiments ended in abrupt decline in pressure values; however, some teeth were only cracked rather than VRF. The maximal pressure the tooth sustained before failure was considered as the bursting pressure. No significant difference were found between the pressure that caused a crack (233±44 bar) and VRF (216±75 bar) ($p=0.62$). Maximal strains at failure were significantly higher ($p<0.001$) in mesial and distal aspects (1120±584 µstrain), than those that developed in the buccal and lingual aspects (584±365 µstrain). Pressure at failure was significantly lower (185.2±32.2 bar) in premolars compared to incisors (253.3±51 bar) ($p=0.001$). Morphologic parameters in which incisors and premolars differed significantly were higher bucco-lingual to mesio-distal root diameter ratio (more oval) in premolars, and total proximal (mesial + distal) root wall thicknesses, higher in incisors than in premolars. However, most of failures patterns were observed at buccal and lingual surfaces. A positive correlation was found between pressure at failure and proximal root wall thickness and a negative correlation between this pressure and the outer oval form.

Discussion

Strain measurements at the outer root surface did not predict on the fracture location. On the contrary, the maximal circumferential tensile strain occurred on the mesial and distal aspects while fracture mostly appeared in the buccal aspect where the root thickness was higher. Oval-shaped root canals create higher tensile stresses at the buccal and lingual inner surfaces, compared to more rounded canals. The proximal wall thickness leads to higher radial stresses that cause the tensile stresses on the inner side of the buccal surface.

Conclusion

1. Hydrostatic pressure applied into root canal eliminates wedge effects of loading instruments; however, meticulous care is required in preparing the specimens.
2. The root canal shape is the parameter that mostly influences the occurrence of root failure.

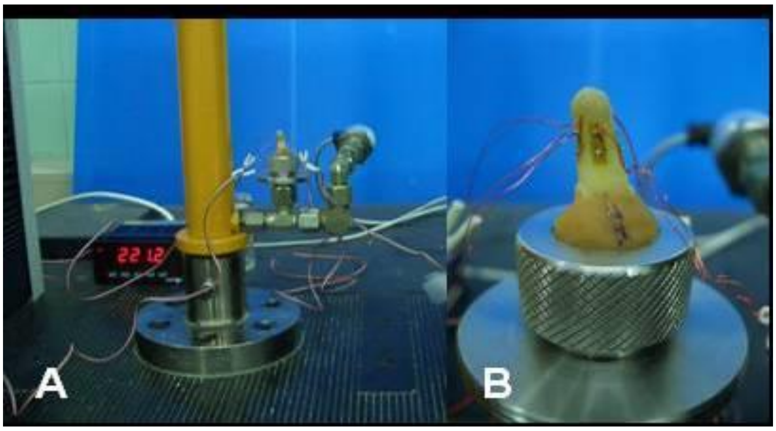

Fig. 1: (A) Experimental setup (B) Close-up of the tooth root with the strain gages

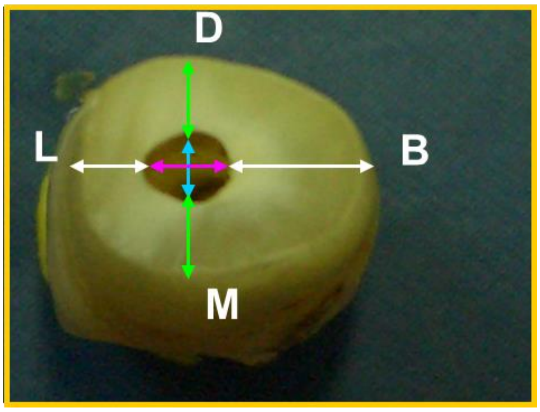

Fig. 2: Morphologic parameters of root dentine: B – buccal, M – mesial, L – lingual, D-distal.

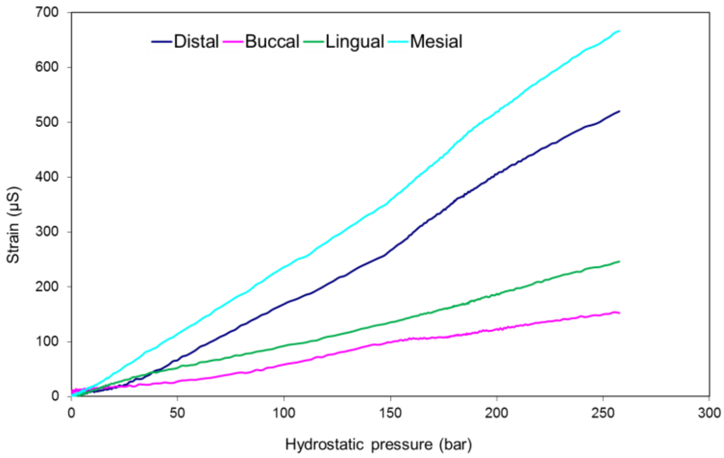

Fig. 3: Strains – pressure diagrams obtained during loading a maxillary incisor.

References

[1] D.S Brauer, G.W Marshall and S.J. Marshall. *Variations in human DEJ scallop size with tooth type*. J. Dent. Vol 38 (2010), p. 597-601.

[2] C. Bellucci and N. Perrini. *A study on the thickness of radicular dentine and cementum in anterior and premolar teeth.* Int. Endod. J. Vol 35 (2002), p. 594-606.

[3] C. Sathorn, J. Palamara and H. Messer. *A comparison of the effects of two canal. preparation techniques on root fracture susceptibility and fracture pattern.* J. Endod..Vol 31 (2005), p. 283–287.

[4] R. Pilo, Z. Metzger and T. Brosh. *Effect of root morphology on the susceptibility of endodontically treated teeth to vertical root fracture: An ex-vivo model.* J. Mech. Behav. Biomed. Mater. Vol 69 (2017), p. 267-274.