Indentation-Induced Microdamage in Human Dentin.

[1,2]Eltit, F; [1,2]Ebacher, V; + [1,2]Wang, RZ

[1]Department of Materials engineering, University of British Columbia, Vancouver, BC, Canada. [2]Centre for Hip Health and Mobility, Vancouver, BC, Canada.

Introduction

Dentin is an anisotropic and highly organized nanocomposite with its mineralized collagen fibrils oriented along the incremental lines. These incremental lines are transverse to the dentinal tubules. Interestingly, a layer of hypermineralized peritubular dentin surrounds the dentinal tubules in the crown, but in the root dentin. The morphological anisotropy of dentin has been described to generate anisotropic mechanical properties to the tissue[1,2]. However the mechanical differences generated by structural differences in coronal vs root dentin have not been fully understood. The aim of the present study is to compare the deformation and microcracking process in crown and root dentin, with special emphasis on the roles of the structural components in those tissues.

Methods

Four human third molars extracted for orthodontic indication where embedded in epoxy resin (Epothin, Buelher) and mechanically ground and polished (Beta, Buehler) in mesio-distal orientation (Fig. 1), then stored in PBS (pH 7.2, 4 C) until tested.

On the distal part of the molars, four Vickers indentations were made at 1 Kg force for 15 seconds. In the mesial half, four spherical indentations (Brinell, 1mm) were made at 30 Kg force for 30 seconds (Fig 1). All of the tests were performed under wet conditions. The samples were then dehydrated on a series of ethanol for 24h and stained with fluorescein in 70% ethanol for 24 hours. They were finally rinsed in 100% ethanol for 24 hours and air dried.

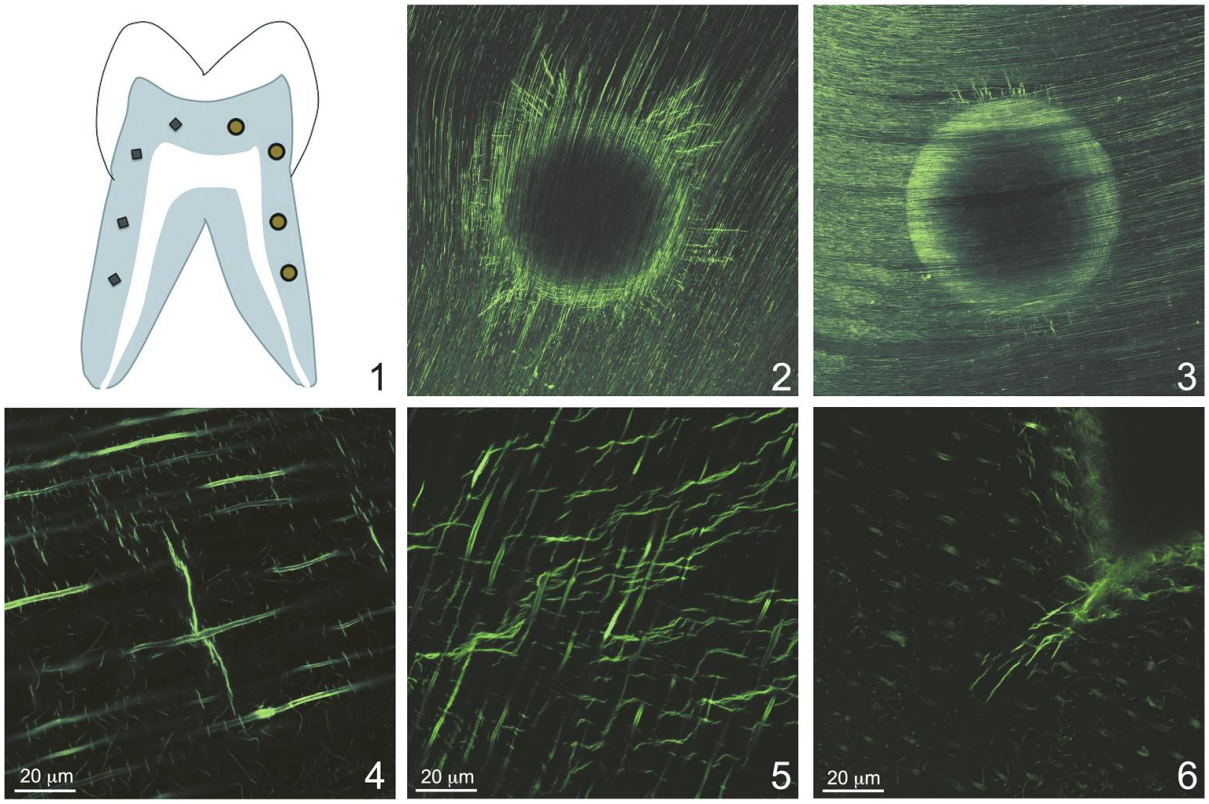
The samples were then observed under an epifluorescence microscope and a Lasser Scanning Confocal Microscope (LSCM) microscope (LSCM; Olympus FluoView FV1000).

Results

The LSCM observation of spherical indentations at low magnification showed different patterns of microcracking around the indents. In the crown the microcracks distribute homogeneously around the indents, radiating out in a sunshine pattern (Fig. 2). In the root the cracks were oriented in the coronal-apical orientation, with few cracks in other orientations (Fig. 3). The angles between the cracks and the dentinal tubules were thus different. In crown the cracks angles distribute randomly, with peaks at 0, 45 and 180 degrees, while in the root the cracks were aligned in specific angles with average inclination of 92 degrees to dentinal tubules following the incremental lines orientation.

An interesting observation was the presence of ring-shaped-cracks in the coronal and root samples. Those microcracks are 5-7 um diameter and are oriented roughly perpendicular to dentinal tubules. In some cases they coalesce to form larger cracks transversal to tubules (Fig. 4). When cracks parallel to dentinal tubules were observed they appeared to connect cracks from different side of the dentinal tubules in a stair-shape crack (Fig. 5). The microcracks generated at the tips of the Vickers indentations showed an interesting shape. At the beining they followed the

original orientation of the romboid tip, however as they propagated into the tissue they started to turn towards the incremental lines orientation.



Figures: 1 Schematic of tooth prepareation and indents location. 2 Coronal dentin Brinell indentation under LSCM. 3 Root Brinell indentation under LSCM. 4 Ring-shape microcracks and crack propagation in root dentin. 5 Stair-shaped cracks in coronal dentin. 6 Crack orientation on rhomboid indentation.

Conclusions

Our results demonstrates that coronal and root dentin are different in microcracking mechanisms. Microcracking in root dentin strongly depends on the orientation of collagen fibrils, while in coronal dentin this effect seems to be counterbalanced by the presence of dentinal tubules and peritubular dentin. The formation of ring-shaped microcracks along the dentinal tubules is an important mechanism of crack nucleation.

References: 1. Inoue, T., et al. Dental materials journal 31.4 (2012): 541-8. 2. Nalla, RK, JH Kinney, and RO Ritchie. Biomaterials 24.22 (2003): 3955-68.3. Wang, RZ. Dental Materials 21.5 (2005): 429-36.