Objective: The objectives of this study are to 1) describe a novel technique for characterizing beam hardening artifacts on cone beam computed tomography (CBCT) images produced by three root canal filling materials; 2) to evaluate the effects of a zirconium-based (Zr) root canal filling material on the production of the beam hardening artifact; and 3) to evaluate the influence of a novel Zr root-filling material using CBCT in the in vitro detection of vertical root fracture (VRF).

Material and Methods: The palatal root canals of four phantom tooth models were endodontically treated using a gutta-percha (GP) root filling material, a Zr root filling material and calcium hydroxide paste. Each phantom tooth was individually imaged using the Carestream 9000 CBCT unit at a native voxel resolution of 76 µm, and the light and dark components of the beam hardening artifact were quantified separately using ImageJ software along three regions of the root canal. The in vitro study used a sample of 176 single-rooted mandibular premolar teeth. One-half of these (88) teeth were filled with GP and half were filled with a Zr material. VRFs were induced in 44 teeth in each group using an Instron Universal Testing Machine. Each root was then placed in a dry human mandible and imaged with a Carestream 9000 3D CBCT device at the native voxel resolution of 76 µm. The images were evaluated by 6 examiners (2 oral maxillofacial radiologists and 4 resident oral and maxillofacial radiologists). Results: A statistically significant difference in the measurement area of the ‘dark’ portion of the beam hardening artifact was found between the 3 treatment groups and in all regions of the phantom tooth root (p<0.05). GP root filling material showed a significantly higher measurement of the ‘dark’ artifact compared to the Zr root filling (p<0.05). A statistically significant difference was also found between all three regions of the tooth roots for the ‘light’ artifact (p < 0.001). The in vitro study showed that sensitivity was greater for detecting VRFs in the Zr group than the GP group (p=0.035). However, the specificity was greater for the GP group than the Zr group (p=0.028). Statistically significant differences were, however, found for the oral maxillofacial radiologists for the Zr group with respect to specificity (p=0.006) and positive predictive value (p=0.012). Conclusion: The use of root canal filling materials with lower K-edge material properties can reduce beam hardening artifact along the length of the root canal. The putative reduced beam hardening artifact of the Zr group improved the sensitivity of detection of artificially induced VRF. The ability to detect VRF in the Zr group was further enhanced by clinical experience.