A novel methodology for analyzing strains developed in endodontically treated teeth rehabilitated by post-core–crown

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Introduction

The traditional approach for restoration of endodontically treated teeth with moderate-to-severe tooth substance loss is to make a post and core and, subsequently, place a crown. This procedure is a precipitating factor for vertical root fracture (VRF). In order to explain that complication research focused on: the influence of dehydration on the mechanical properties of dentin, the reduced residual dentin thickness, iatrogenic induced micro-cracks and the interaction of the post with those cracks. Cast posts and cores are considered as the preferred treatment of choice for anterior teeth with severe destruction. Better prognosis is achieved upon incorporation of 2mm of crown ferrule on sound dentin. The effectiveness of the ferrule has been previously evaluated by analyzing the stress distribution in the post and cervical dentin. Stress distribution in the post was analyzed indirectly by methods of finite element and photoelastic analysis but direct method was never described. The aim of this study was to present a novel methodology for measuring directly the strains in the intra-radicular post and to evaluate the effect of ferrule and crown cementation on those strains.

Materials and Methods

Twelve extracted central incisors bovine teeth, with similar morphology but greater dimensions as compared to human teeth, were collected. The incisal surfaces were horizontally reduced 5mm coronal to the CEJ, obtaining a flat surface. The root canals were prepared with K files to #140. The axial surfaces were prepared to receive a full coverage metal crown with light chamfer finishing line. Post and cores were fabricated using burnout plastic posts coated in increments with pattern resin to an intracanal depth of 8mm from the buccal CEJ and extra coronal height of 5mm and cast with Ni-Cr alloy. The buccal and lingual surfaces of the intra-canal cast post were reduced by 0.4mm to enable bonding of miniature strain gauges. Four miniature strain gauges (EA-06-031DE-350) with an active gauge length of 0.79 were bonded at the same plane: two on the buccal and lingual surfaces of the post and two on the buccal and lingual external surfaces of the root dentin. The strain gauges were mounted to measure circumferential strains. Electric wires 134-AWP connected the strain gauges to computerized data acquisition system by passing along the root canal and out through the apex of the root. Cementation of the cast post and core was done by ZPC. The root was dipped in Provil L impression material, obtaining film thickness of 0.2-0.3, simulating the PDL, and embedded in a PVC cylinder with Epoxy resin (PC-1). The electric wires were soldered to terminals (CPC-25), connected through three-wire quarter Wheatstone bridge circuit design to data acquisition system (System 2100). For each tooth 6 Ni-Cr full coverage cast crowns were fabricated covering the 5mm core and varying degrees of dentin ferule: 5, 4, 3, 2, 1, 0 mm. The epoxy cylinders were inserted to an adjustable loading apparatus and the un-cemented and cemented (ZPC) crown was loaded via a loading machine at angulations of 0º, 15º, 30º and 45º. The crown was loaded in a crosshead speed of 0.5mm/min up to 100N with continuous force and strain acquisition at 10Hz. After each experiment the crown was removed by gentle cutting and a new crown with a different amount of ferrule was tested- initially un-cemented and afterward cemented. The loading was repeated as described. At the end of all experiments 48 plots were obtained for each tooth (4 angulationsX6 ferrule configurationsX2 conditions- cemented/un-cemented). Data was analyzed by two ways ANOVA with repeated measures; dependent variable: strain, independent variable: angulation and amount of ferrule. The strain at 100N was taken as a representative value. Statistical analysis was done by two-way ANOVA with repeated measures.

Results

The buccal and lingual surfaces of the post and root were characterized by negative (compression) and positive (tension) strains. The strains linearly increased with increasing load ($r>0.94$, $p<0.01$). Higher angulations of load were characterized by higher absolute values of strain. The correlations between buccal and lingual post strains were highly significant ($p=0.001$) and increased gradually from 0º (-0.838) to 45º (-0.969). On the other hand the correlations between post and root strains decreased in both the buccal and lingual aspects from 0º (0.796-0.847) to 45º (0.454-0.528) (p=0.001).With decreasing amount of ferrule, the absolute values of strain on the post increased, but those on the root remained relatively constant. For example; at 30º angulation the strains on the root were approximately ±400µs at all ferrule configurations whereas those on the post increased from approximately ±100µs at 5mm ferrule to ±700µs at 0mm ferrule (Fig.1).

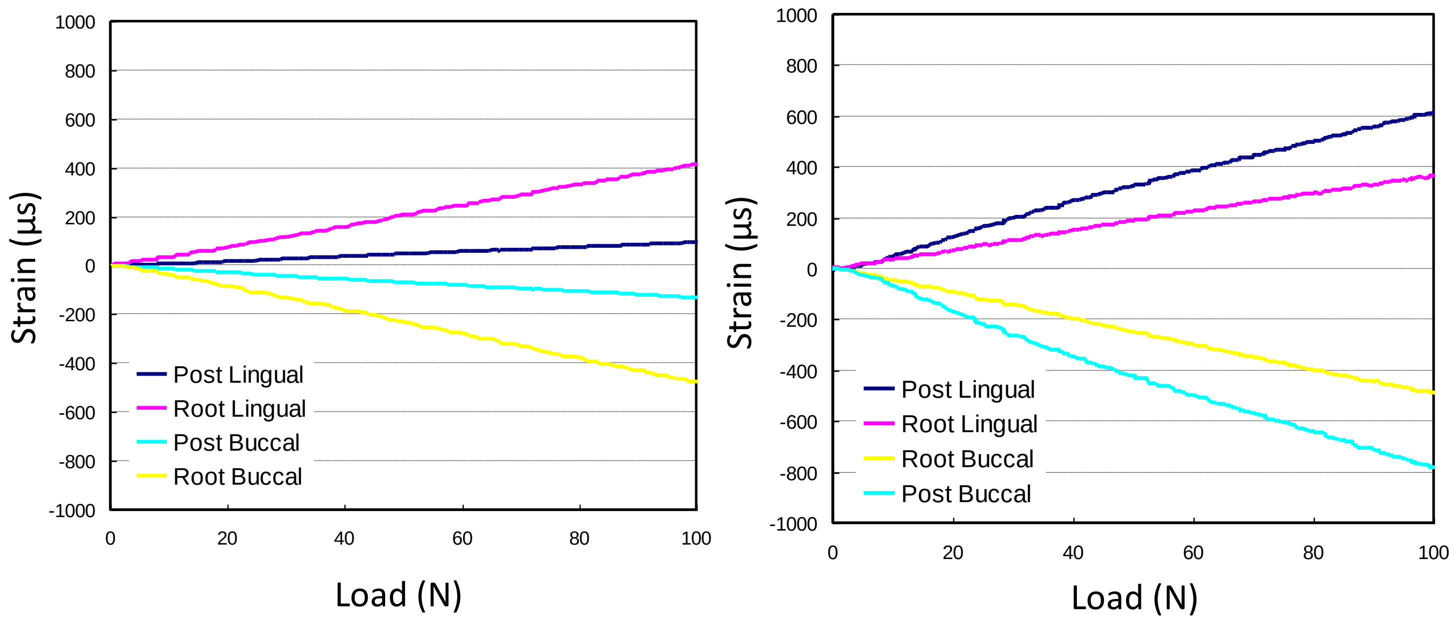

Fig. 1 Strains on post and root at 5mm ferrule (left) and 0mm ferrule (right) while loading the cemented crown at 30º. Note that the strains on the root were similar whereas those on the post increased >6 fold.

The strain on the buccal and lingual surfaces of the post differed significantly between each ferrule and the preceding one and between each load angulation and the preceding one (p<0.003). However an interaction exists between these two variables. The main decrease in strain occurred between 0 and 1mm (55%) or 2mm (72%), the remaining 3-5mm of ferrule contribute to additional decrease of 28%. The strains developed on the root did not differ significantly between each ferrule and the preceding one (p>0.11); however a significant differences exists between each load angulation and the preceding one (p<0.001). When comparing the results between cemented and un-cemented crowns having the same ferrule, the strains on the post decreased dramatically only after cementation (p=0.001). The influence of the cement is more pronounced as the ferrule is maximized.

Conclusions

The strains on the root surface are not influenced by the amount of crown ferrule; however the strains on the intra canal post decreased significantly as the amount of ferrule increased (three times higher in 0mm compared to 5mm). Crown cementation has an important role in reducing the intra canal stresses induced by the post, probably reducing the risk of vertical root fracture.