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Strain measurements and fracture resistance of endodontically treated premolars restored with all-ceramic restorations

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Objectives: The aim of this study was to investigate the recovery of cuspal stiffness and fracture resistance in endodontically treated maxillary premolars restored with bonded ceramic inlays and onlays of various designs.

Methods: Seventy intact premolars were selected for this study; six cavity designs were investigated: (i) mesio-occlusal-distal (MOD) inlay (I), (ii) MOD inlay with palatal cusp coverage (IPC), (iii) MOD onlay (O), (iv) MOD inlay with pulp chamber extension (IPE), (v) MOD inlay with palatal cusp coverage and pulp chamber extension (IPCPE), and (vi) MOD onlay with pulp chamber extension (OPE). Intact teeth acted as control. Strain gauges were attached to the buccal and palatal surfaces of the teeth to measure cuspal stiffness under static loading. All specimens were eventually subjected to compressive load to failure. Cuspal stiffness and fracture resistance data were analyzed using ANOVA and Tukey test.

Results: The I and IPE restorations restored cuspal stiffness to 75% of the sound tooth value. The O and OPE restored teeth had stiffness values greater than that of a sound tooth. The I, IPC, O, IPE, IPCPE and OPE restored teeth demonstrated fracture strength values of 938 N $\pm$ 113 N (s.d.), 1073 N $\pm$ 176 N and 1317 N $\pm$ 219 N, 893 N $\pm$ 129 N, 1062 N $\pm$ 153 N and 1347 N $\pm$ 191 N respectively.

Conclusions: Within the limitations of this study, it was concluded that the all-ceramic onlay or inlay with palatal cusp coverage provided best biomechanical advantage in restoring an endodontically treated maxillary premolar tooth.

Clinical significance: The onlay approach which is more conservative compared to full coverage restoration is considered an appropriate approach to the restoration of endodontically treated maxillary premolars. The addition of a pulpal extension to the all-ceramic restorations, apart from being technically challenging, was not found to offer any biomechanical advantage to the restored teeth.

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1. Introduction

Traditionally, endodontically treated posterior teeth tended to be restored with the aid of a radicular metallic post in the unsubstantiated belief that a rigid post would reinforce the tooth.[1–3] The use of a rigid, metallic post in the restoration of an endodontically treated tooth is now known to weaken rather than strengthen remaining tooth tissues with post canal preparation[4,5] and post placement being associated with the risk of root perforation and radicular fracture in clinical service.

One of the important criteria to ensure clinical success of endodontically treated teeth is the provision of cuspal coverage. This has been shown in a retrospective study done by Sorensen and Martinoff[2] – a study which include 1273 endodontically treated teeth restored with/without coronal coverage restorations. The study found that coronal coverage did not significantly improve the success of endodontically treated anterior teeth. However, the study found a significant improvement in the clinical success of maxillary and mandibular premolars and molars when coronal coverage restorations were present.

Currently, adhesive techniques are widely used in the restoration of endodontically treated teeth to increase the stiffness of the restored tooth unit, and protect the restored tooth against fracture in clinical service.[6–8] This has been considered to be of particular importance in the restoration of endodontically treated posterior teeth.[9] The strengthening effect of adhesive restorative techniques in such situations has been shown to restore cuspal stiffness, often to a level comparable to that found in intact teeth.[10–13] Clinical studies have provided supportive evidence, demonstrating the effectiveness of, in particular, various all-ceramic systems.[14,15]

To avoid post canal preparation and take advantage of the versatility of CAD-CAM technology in the restoration of endodontically treated posterior teeth, it has been suggested that the pulp chamber be used to create and retain an ''endo-type'' crown – a ceramic crown extending into the pulp chamber for additional retention and resistance.[16] The extension of restorations into the pulp chamber, with or without conservation of coronal tooth tissues[8,17] may, however, adversely affect the biomechanical behaviour of the restored tooth unit.[18]

In this laboratory-based study, endodontically treated maxillary premolar teeth were restored with bonded ceramic inlays and onlays, including designs having pulp chamber extensions to investigate the recovery of cuspal stiffness and fracture resistance of the restored tooth units. The aim of the study was to identify the design of all-ceramic restoration best able to restore the biomechanical properties of a maxillary premolar tooth subsequent to endodontic treatment. The specific hypothesis was that the addition of a pulpal extension to certain designs of all-ceramic restorations would offer no advantage in terms of the stiffness and fracture resistance of prepared and restored endodontically treated maxillary premolar teeth.

2. Materials and methods

Seventy sound, single-rooted maxillary premolar teeth, extracted for either orthodontic or periodontal reasons, and which satisfied a series of selection criteria aimed at limiting the effects of tooth related factors, were collected and stored in 0.5% chloramine solution. The teeth were individually mounted perpendicular in cold-cure epoxy resin (Mirapox 950-230, Miracon, Malaysia) to a level 2.0 mm apical to the cementoenamel junction (CEJ). The mounted teeth were divided at random into seven test groups of 10 teeth, each of which was assigned to receive one of the selected preparation designs: (a) mesio-occlusal-distal (MOD) inlay (I), (b) MOD inlay with palatal cusp coverage (IPC), (c) MOD onlay (O), (d) MOD inlay with pulp chamber extension (IPE), (e) MOD inlay with palatal cusp coverage and pulp chamber extension (IPCPE) and (f) MOD onlay with pulp chamber extension (OPE) (Fig. 1). The seventh group of teeth acted as a control group. The preparations for groups (d)–(f) extended into the pulp chamber to the level of the CEJ and have a butt joint with the composite restoration in the pulp chamber.

Root canal treatment (RCT) was performed in all the intact teeth assigned for preparation. The laterally condensed gutta-percha was removed to 2.0 mm below the CEJ. The access cavity was then fully restored by means of a bonded resin composite restoration (Prime & Bond® NT™, SPECTRUM® TPH®3, Dentsply, Germany).

The preparations had an isthmus width of one-third of the intercuspal distance. The occlusal section was 2.0 mm deep, with the pulpal floor prepared at right angles to the long axis of the mounted tooth. The buccolingual width of each proximal box was half the width of the proximal surface of the tooth. The 1.5 mm wide gingival floors were placed 1.0 mm above the CEJ. The palatal cusp was reduced by 2.0 mm and the buccal cusp by 1.5 mm in the cuspal coverage preparations. The preparations with pulp chamber extensions were prepared apically to the level of the CEJ.

The all-ceramic restorations were constructed from Pro-CAD® blocks (Ivoclar Vivadent AG, FL-9494 Schaan, Liechtenstein) using a CEREC machine (Sirona Dental Systems GmbH, Bensheim, Germany). All the restorations were adhesively cemented using Prime & Bond NT and Calibra resin luting cement (Dentsply Caulk, Milford, USA).

Strain gauges with an internal resistance of 120 Ω and gauge length of 1.0 mm (TML FLA-1-17-3L, Tokyo Sokki Kenkyujo Co., Tokyo, Japan) were bonded to the buccal and palatal surfaces of the teeth. During investigation the strain gauges were connected to a strain data logger (NMB Multipoint Data Processor DPU-103, MINEBEA Co. Ltd., Japan) to complete a Wheatstone bridge circuit, with the voltage output from the bridge being directly proportional to the deformation of the specimens. The output signal was recorded as microstrain ($\mu\varepsilon$). Strain readings of the teeth under axial static loading (150 N) were obtained at three stages: (1) prior to preparation of the tooth, (2) following endodontic treatment and cavity preparation, and (3) after restoration with the assigned bonded all-ceramic restoration.

The strain data were then computed to obtain relative stiffness (RS) values[19]:

$$\text{Relative stiffness (RS)} = \frac{\text{maximum strain in the unaltered tooth}}{\text{maximum strain under the test condition}}$$

These calculations provided unitless values. The sound tooth was given the value of one. Relative stiffness values of