Patient-specific Finite Element Analysis of Fiber Post and Ferrule Design

Monise de Paula Rodrigues, DDS, [*] *Priscilla Barbosa Ferreira Soares, DDS, MSc, PhD,* [†] *Andréa Dollores Correia Miranda Valdivia, DDS, MSc, PhD,* [*] *Roberto Sales Pessoa, DDS, MSc, PhD,* [*] *Crisnicaw Veríssimo, DDS, MSc, PhD,* [‡] *Antheunis Versluis, PhD,* [§] *and Carlos José Soares, PhD* [*]

Abstract

Introduction: A ferrule on anterior endodontic-treated teeth has been evaluated using clinical trials, *in vitro* tests, and finite element analysis (FEA). The patient-specific FEA with a nonuniform ferrule and nonlinear contact biting load associated with clinical validation can be used to predict failure. **Methods:** A patient was selected with both maxillary central incisors with different ferrule designs who received endodontic treatment and restoration using a fiber post, composite core, and computer aided design and computer aided manufacturing lithium disilicate ceramic crowns. Strain gauges were attached to the buccal surfaces of both teeth to record ceramic strain during bite force recording for FEA validation. Cone-beam computed tomographic imaging was performed, and the Digital Imaging and Communication in Medicine files were exported to Mimics, 3-Matic (Materialise, Leuven, Belgium) and Patran (MSC Software, Santa Ana, CA) software to create a patient-specific FEA model. Bite load was applied using contact load applied by antagonist teeth (155 N). Mechanical properties were obtained from the literature. Modified von Mises equivalent stress was used for stress evaluation. **Results:** Stresses on the dentin and fiber post on the left incisor, which had a nonuniform ferrule, were higher compared with the right incisor. The strain values recorded for the right central incisor (strain gauge =79.9 $\pm$ 3.8 μS and FEA = 69.5 μS) and the left central incisor (strain gauge = 83.5 $\pm$ 5.3 μS and FEA = 73.9 μS) validate the FEA analysis. **Conclusions:** FEA was validated with *in vivo* strain values measured at the buccal crown surfaces, supporting that the stress levels were realistic for investigation of the clinical performance of fiber posts. Maintaining a uniform ferrule was more favorable than a localized higher ferrule. *(J Endod 2017;■:1–6)*

Key Words

Endodontically treated teeth, fiber post, finite element analysis, patient-specific model, stress

Significance

Patient-specific finite element analysis provided realistic stress investigation that may be used with clinical analysis of fiber posts. This study showed that the uniform ferrule tends to be more favorable than a localized higher ferrule in anterior endodontic-treated teeth.

The restoration of severely damaged, endodontically treated teeth commonly requires post and core restorations for retention purposes (1, 2). Fiber posts have been used clinically as an alternative to metal posts in the restoration of endodontically treated teeth (3–5). The amount of remaining coronal and root dentin after root canal instrumentation and post space preparation are associated with stress concentration and fracture resistance (2, 6, 7). A recent meta-analysis suggested that the absence of the coronal wall might increase the risk of fiber post–core restoration failure, whereas the role of the ferrule effect is still not entirely understood (8). Other studies reported that the presence of a uniform ferrule surrounding the remaining tooth structure enhanced fracture resistance (2) and increased the long-term success of anterior teeth with posts (5).

Numerous finite element analyses (FEAs) have studied the ferrule effect in anterior endodontic-treated teeth for factors such as remaining dentin thickness (9, 10), ferrule height, and configuration (6,11–13). However, these studies used FEA models that were created using general data of the anterior teeth and geometric computer aided design (CAD) modeling and standardized the ferrule designs to isolate a specific factor. Nowadays, computed tomographic scan data allow efficient generation of specific 3-dimensional (3D) models (14, 15). These models can be used to address individual clinical cases. Using identification of the remaining tooth structure and restorative materials by radiodensity levels, realistic individual models can be created to represent the specific conditions of a patient (15). The creation of patient-specific FEA studies of endodontic-treated teeth restored with fiber posts that represent a real nonuniform ferrule presence loaded with nonlinear antagonist bite load application followed by direct clinical validation using the specific patient case could be a very important tool to predict failure. Besides validation and data correlation, a patient-specific FEA approach advances the goal of personalized health care in dentistry. The aim of this study

From the Departments of *Operative Dentistry and Dental Materials and [†]Periodontology and Implantology, School of Dentistry, Federal University of Uberlândia, Minas Gerais, Brazil; [‡]School of Dentistry, University of Uberaba, Minas Gerais, Brazil; and [§]Department of Bioscience Research, College of Dentistry, University of Tennessee Health Science Center, Memphis, Tennessee.

Address requests for reprints to Carlos José Soares, Biomechanics Research Group, Federal University of Uberlândia, School of Dentistry, Avenida Pará, 1720, Bloco 4L, Anexo A, Sala 42, Campus Umuarama, Uberlândia, Minas Gerais, Brazil 38405-320. E-mail address: carlosjsoares@ufu.br

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was to present a protocol and validate the generation of a 3D patient-specific finite element model using cone-beam computed tomographic imaging to test the effect of ferrule designs on left and right maxillary central incisors restored with glass fiber posts and CAD-computer aided manufacturing (CAM) all-ceramic restorations.

Materials and Methods

Patient Rehabilitation

This study had the approval of the ethics committee (#144.423/2012). One patient with 2 maxillary central incisors who needed periodontal surgery; endodontic treatment; and fiber post, composite core, and all-ceramic crown rehabilitation was selected. Periodontal surgery was performed, and the root canals were instrumented with a size 80 master apical file (K-file; Dentsply Maillefer, Ballaigues, Switzerland). Canals were rinsed with 1.0% sodium hypochlorite (Cloro Rio 1.0%; São José do Rio Preto, SP, Brazil) and physiological saline and filled with gutta-percha (Dentsply, Petrópolis, RJ, Brazil) and calcium hydroxide–based endodontic sealer (Sealer 26, Dentsply). Root canals were prepared using a dedicated drill for conic smooth glass fiber posts (Exacto Translucido no. 3, Angelus). The smooth conical fiber post used was 1.6 mm in diameter at the coronal portion and 0.9 mm at the apical portion. The posts were immersed in 24% hydrogen peroxide (Dinâmica, SP, Brazil) followed by a silane coupling agent (Silano, Angelus) application for 1 minute (16). The posts were luted with self-adhesive resin cement (RelyX Unicem 2; 3M ESPE, St Paul, MN). After 5 minutes, the resin cement was light activated on each surface for 40 seconds with a light-emitting diode unit (Radii-Cal; SDI, Bayswater, Australia). The remaining coronal tooth was etched using 37%

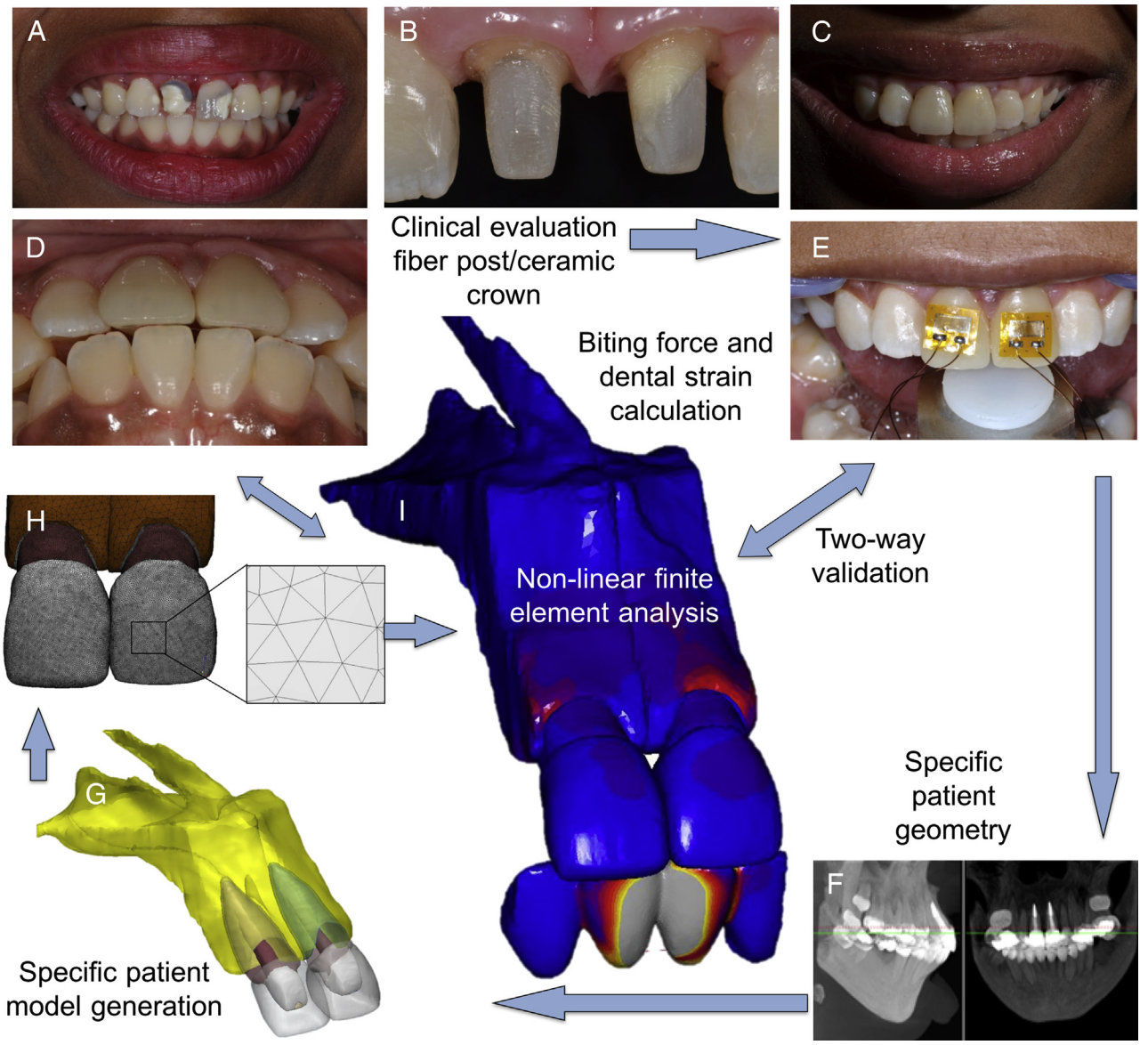

Figure 1. A schematic showing the approach for developing a patient-specific finite element model and clinical validation. (*A*) The initial conditions of severe dental structure loss. (*B*) Tooth preparation of the glass fiber post/composite core. (*C*) The final rehabilitation. (*D*) The initial contact of antagonist teeth during protrusive jaw movement. (*E*) Strain gauge measurement and bite force recording for both teeth together. (*F*) Cone-beam computed tomographic image after teeth rehabilitation. (*G*) The final mesh created with Mimics, 3-Matic, and Patran software. (*H*) Material and structure segmentation for model generation. (*I*) Nonlinear analysis simulating the biting force with clinically obtained inputs.