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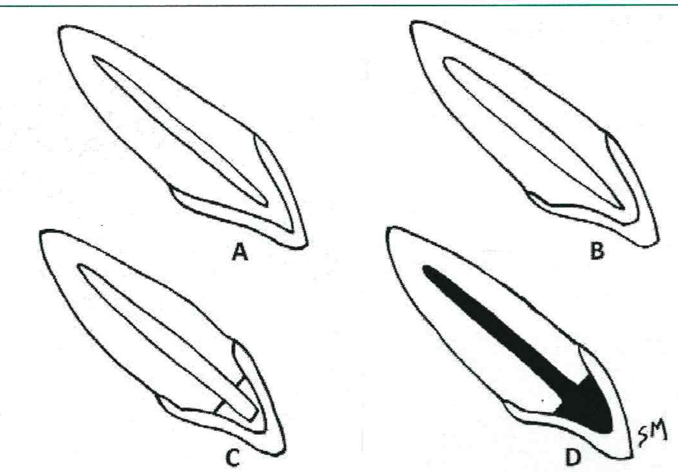

A finite element analysis study evaluated the strength and adhesion of cast posts vs glass fiber-reinforced composite posts for a maxillary central incisor: A, intact tooth; B, tooth with ceramic crown; C, tooth restored with glass fiber-reinforced composite post with composite resin core; and D, tooth restored with cast post-and-core made from gold alloy or nickel-chromium alloy. See *STRENGTH AND ADHESION OF CAST POSTS COMPARED WITH GLASS-FIBER POSTS.*

Finite Element Analysis in Prosthodontics

Finite element analysis (FEA) solves an intricate mechanical problem by representing the geometry of interest on a computer and defining the elements by considering the manner in which nodes are located in 2-dimensional or 3-dimensional (3D) space. This method of analysis has proven valuable in improving the profession's understanding of various aspects of oral biomechanics and can be applied to various specialties. This issue of *Prosthodontics Newsletter* is devoted to a series of articles related to FEA and prosthodontics.

Strength and Adhesion of Cast Posts Compared with Glass-fiber Posts

Posts are commonly used to restore endodontically treated teeth. Custom-cast metal posts are the traditional post system, but prefabricated fiber-reinforced composite (FRC) resin posts have gained in popularity. The strength and longevity of a restored pulpless tooth can depend on the post material, the length of the post, the thickness of remaining root dentin, the length of the root, the post's bond to

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Strength and Adhesion of Cast Posts Compared with Glass-fiber Posts

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dentin, remaining coronal tooth structure, the ferrule and the load applied to the tooth. The effect of the post's fabrication material on the strength of the restored tooth remains controversial.

Dejak and Młotkowski from the Medical University, Poland, undertook an FEA study to evaluate the strength of teeth restored with cast posts and glass FRC posts, along with the bond strengths of the posts to dentin. Using FEA software (ANSYS v. 10; ANSYS, Inc., Canonsburg, Pa.), 3D models of maxillary central incisors were generated. The models (see cover illustration) included

- intact tooth
- tooth restored with a ceramic crown
- tooth restored with glass FRC post and composite resin core
- tooth restored with gold-alloy cast post
- tooth restored with nickel-chromium (NiCr)–cast post

Each model was subjected to vertical and oblique simulated loads with a force of 100 N (Figure 1).

- The modified von Mises failure criterion was used to evaluate the overall strength of the restored tooth, ceramics and composite resin.
- The Tsai-Wu criterion was used for the FRC post.
- The von Mises criterion was used for the gold- and NiCr-alloy posts.

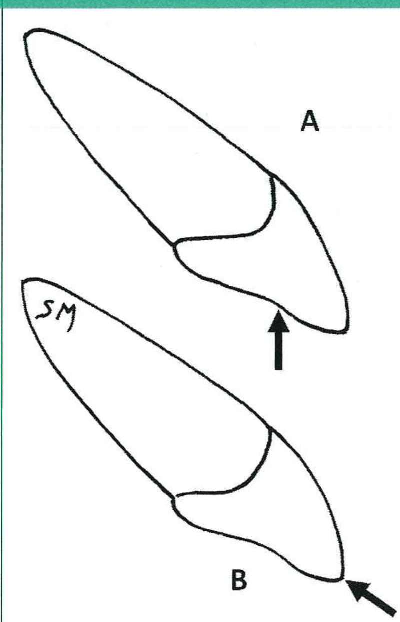
Compressive, tensile and sheer contact stresses at the cement-dentin interface around the posts and beneath the crowns were calculated.

Regardless of the material used, the equivalent stresses in posts did not exceed their tensile strengths. Compared with FRC posts, lower stresses occurred in the luting cement and the cement-dentin interface around cast posts. The stresses for the ceramic crown supported by a metal post-and-core were lower compared with the crown supported with the composite resin core foundation.

Comment

Results of this study suggest that, compared with FRC posts, metal posts will reduce stresses in dentin because of their higher elastic modulus, possibly reducing the potential for the tooth to fracture. Also, ceramic crowns supported by composite resin will experience higher stresses, which could increase the potential for fracture of the crown.

Figure 1. Oblique load on palatal surface (A). Vertical load at incisal edge (B).



Dejak B, Młotkowski A. Finite element analysis of strength and adhesion of cast posts compared to glass fiber-reinforced composite resin posts in anterior teeth. J Prosthet Dent *2011;105:115-126.*

Stresses on Implants Related to Cantilever Length And Angulation

When fabricating a complete-arch implant-supported fixed restoration in the atrophic maxillary arch, 4 implants are commonly placed: 2 in the canine region, bilaterally, and 2 on each side, as far posteriorly as practical. The posterior implants are usually short (<10 mm) because of the maxillary sinuses, and the prosthesis has bilateral cantilevers to provide a molar tooth on each side.

An alternative to the traditional arrangement is the method in which the 2 posterior implants are tilted distally at an angle up to 45°, avoiding the maxillary sinuses. This oblique implant placement allows for the use of longer implants, optimizes the anterior-posterior spread of the implants and minimizes the cantilever length on the prosthesis while still allowing the placement of a first molar tooth on each side.

Bevilacqua et al from the University of Genoa, Italy, conducted a 3D FEA to evaluate the stresses transmitted to tilted vs vertically placed implants in the maxillae and to analyze stresses transmitted to the surrounding bone.

For the FEA, a 3D edentulous model of the maxillae was designed with computer software (FEMAP 8.3; Siemens PLM Software, Plano, Tex.). Four implants were placed and restored with a fixed implant-supported denture. Four different implant configurations were evaluated, with the 2 distal implants angulated at 0°, 15°, 30° and 45°.

The length of the prosthesis remained constant; when the tilt of the implants was increased, the cantilever became shorter. Cantilever lengths were 13 mm, 9 mm, 5 mm and 0 mm.

- For vertical implants, all implants were 13 mm long.
- For 15° and 30°configurations, the implants were 15 mm long.
- For 45° configuration, the implants were 18 mm long.

A vertical load of 150 N was applied to the distal portion of each prosthesis on the right side.

Stresses at the peri-implant bone decreased at distal and mesial implants as the inclinations of the distal implants increased and the cantilever lengths decreased. Maximal stress values in compact bone for vertical implants were 75.0 MPa for distal implants, 35.0 MPa for mesial implants and 95.0 MPa for the metal frameworks.

The maximal stress values on the implants were 19.9 MPa for the 45° distal implants and 7.8 MPa for the mesial implants. Stresses on the prosthesis also decreased dramatically as the amount of tilting increased.

Comment

When fabricating a maxillary fixed implant-supported complete-arch fixed denture with tilted distal implants, longer implants can be used, and the cantilever length can be reduced. This method appears to reduce stresses within the peri-implant bone and the prosthesis, improving oral biomechanics.

Bevilacqua M, Tealdo T, Menini M, et al. The influence of cantilever length and implant inclination on stress distribution in maxillary implant-supported fixed dentures. J Prosthet Dent *2010;105:5-13.*

Mechanical Behavior Of Veneered Zirconia-based Crowns

While fracture and chipping of the veneering porcelain of zirconia-based crowns has been reported in the literature, the causes of this problem have not been well understood. An FEA by Rocha et al from São Paulo State University, Brazil, evaluated stress distribution in the feldspathic porcelain veneering ceramics of a zirconia-based crown placed on a maxillary central incisor.

For a complete crown on a maxillary central incisor, the following 3 FEA models were developed:

- feldspathic ceramic crown (MF)
- zirconia-based crown with complete bond between zirconia and veneering porcelain (Mlz)
- zirconia-based crown with an incomplete bond between zirconia and veneering porcelain (Mnzl)

A load of 1 N was distributed (approximately 10 mm^2) and applied to the lingual surface in the incisal third at a 45° angle to the long axis of the tooth for all models. Compared with Mlz, the ceramic veneer for the Mnzl model showed a significant increase in maximal principal stress (12 times) and minimal principal stress (77 times), and similar behavior was noted for the sheer stress values.

Comment

The bond between the zirconia substructure and veneering ceramics is not well understood. The integrity of the bond appears to depend on

- veneering material used
- type of zirconia
- surface preparation and liner material applied to the zirconia
- technique used to apply the veneer

During the layering process, flaws can develop between the zirconia substructure and the veneer. The results of this study suggest that an incomplete bond can induce stresses that could lead to chipping and fracture.

Rocha EP, Anchieta RB, Freitas AC Jr, et al. Mechanical behavior of ceramic veneer in zirconia-based restorations: a 3-dimensional finite element analysis using micro-computed tomography data. J Prosthet Dent *2010;105:14-20.*

Finite Element Analysis of Peri-implant Bone Strain

Strain is induced in the bone surrounding an implant when it is loaded. The effects of the implant's length and diameter, as well as the quality of the surrounding bone, can influence the strain distribution in the peri-implant bone.

Chou et al from Northeastern University, Massachusetts, conducted an FEA study to evaluate the biomechanical response of peri-implant bone to a wide-diameter short (WDS) implant and a narrow-diameter long (NDL) implant. Insertion depths and bone quality were additional variables.

With software (Pro/ENGINEER Wildfire 2.0; Parametric Technology Corp., Needham, Mass.), a computerized tomographic image of the premolar region was used to construct a 3D segment of the mandible. The WDS implant was 5.99 mm long and 5 mm wide; the NDL implant, was 10.96 mm long and 3.5 mm wide.

Simulated occlusal force was generated by the application of 100 N of force to the implant abutment at an angle of 11° from the long axis of the implant in a bucco-lingual direction. Bone strain distributions were measured for 5 different implant insertion depths in 2 levels of bone quality:

- high quality (cortical)
- low quality (trabecular)

The FEA study resulted in high strain levels at the tips of the threads with less strain in the bone within the grooves between the threads. A more uniform and better strain distribution occurred with the WDS implant compared with the NDL implant:

- For the NDL implant, 60%–80% of the peri-implant bone volume was subjected to 200–1000 μstrain (με), and 15%–35% was subjected to 1000–3000 με, for both bone qualities.
- For the WDS implant in low-quality bone, the bone volume subjected to 1000–3000 με increased when compared with the high-quality bone; the bone volume subjected to 200–1000 με decreased.
- For the WDS implant, strain levels decreased with increased insertion depth.
- The influence of insertion depths on overall strain with the NDL implant was limited because most of the strain gradient occurred close to the alveolar crest.

Comment

A more uniform, better strain distribution within the peri-implant bone was recorded for WDS implants compared with the NDL implants. Nevertheless, high strain levels inevitably occurred at the ridge crest, regardless of the implant dimensions or the simulated clinical scenarios. Because different implant insertion depths can cause variations in the peri-implant strain levels, adjusting the implant insertion depth in alveolar bone with compromised quality can induce favorable peri-implant strain levels.

This study assumed that osseointegration with the implant was 100%, which never happens clinically. With lower levels of osseointegration, the bone strain levels would be expected to increase proportionally.

Chou H-Y, Müftü S, Bozkaya D. Combined effects of implant insertion depth and alveolar bone quality on periimplant bone strain induced by a wide-diameter, short implant and a narrow-diameter, long implant. J Prosthet Dent *2010;104:293-300.*

In the Next Issue

- Glass ionomer cement modified with N-vinylcaprolactam
- Dentin conditioning and bond strength of self-adhesive resin cement
- Bond degradation of self-adhesive resin cement

Our next report features a discussion of these issues and the studies that analyze them, as well as other articles exploring topics of vital interest to you as a practitioner.

Do you or your staff have any questions or comments about **Prosthodontics Newsletter**? Please write or call our office. We would be happy to hear from you.