Short Communication

Three-Dimensional Finite Element Analyses of All-Ceramic Posterior Fixed Partial Dentures with Different Designs

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The aim was to evaluate the influence on the stress distribution patterns in and the magnitude of stresses on fixed partial dentures (FPDs) under different anatomic and design conditions. Three-dimensional finite element models of posterior 3-unit all-ceramic FPDs were created with and without periodontal ligaments, with different radii of curvature at the embrasure area, and in a curve shape with a periodontal ligament. The model with a periodontal ligament showed 40% higher stress values compared to the no-ligament model. A smaller radius of curvature resulted in 20% to 40% higher stress values. The curved model increased stress values at the distal connector by 65% compared to the straight model. Support by teeth, occlusal curvature, and a small radius of curvature at the embrasure area negatively affect stress distribution patterns in the connector area of all-ceramic FPDs. *Int J Prosthodont 2007;20:89–91.*

Increasing demand for esthetic materials has focused interest on all-ceramic fixed partial dentures (FPDs). Limited tensile strength and brittleness are weaknesses of ceramics, but the development of materials with superior mechanical properties makes the use of larger constructions possible. Studies have pointed to the connector area as a risk factor for fracture, and in vitro analyses of 3-unit FPDs have verified that cracks are initiated in the connector region,[1,2] as it is the most stress bearing and critical part of the construction.[3,4] Curvature at the gingival embrasure strongly affects fracture resistance of FPDs. Because stress levels vary in different parts of an FPD and failures may appear in both connectors and in crowns, it would be useful to analyze the stress levels in FPDs of differing designs.

Materials and Methods

Three-dimensional finite element models of posterior, noncemented, 3-unit all-ceramic FPDs were created. The dimensions of the FPDs and the points at which stress was measured are presented in Figs 1 and 2. Simulated conditions with and without a periodontal ligament (PDL) (simulating tooth and implant support, respectively) and with radii of curvature of 0.25 or 0.5 mm at the gingival connector/abutment contact area were measured. The PDL (0.2 mm) was designed with only planar contact to bone and root surfaces. A curved model was also created with a radius of curvature of 25 mm and a molar angled by 30 degrees. The moduli of elasticity assigned to portions of the model were 200,000 MPa for zirconia, 13,700 MPa for cortical bone, 1,400 MPa for trabecular bone, and 18,600 MPa for dentin. An occlusal load of 800 N was applied at the central fossa of the pontic. Modeling was performed with ProEngineer Wildfire, and finite element model computations were made with Pro/Mechanica Wildfire (Parmetric Technology). A total of 7,900 elements were used for the model without a PDL, and 15,000 elements were used for the model with a PDL.

Results

In the straight model, the highest stress were concentrated at the connection to the pontic (Table 1). The model with a PDL showed stresses that were more than 40% higher than those in the no-PDL model (Fig 3). A smaller radius of curvature at the connector-pontic area resulted in stresses that were 20% to 40% higher. In the curved model, the stresses increased at

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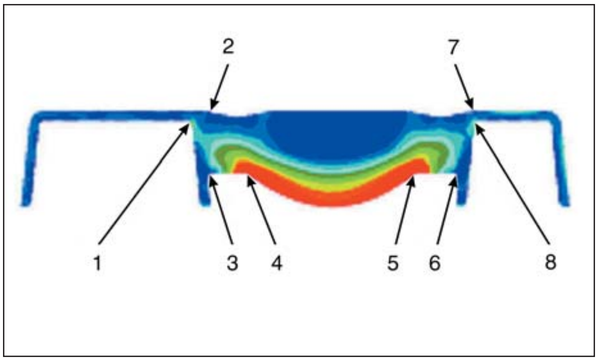


Fig 1 *(above)* Measurement points used in all models.

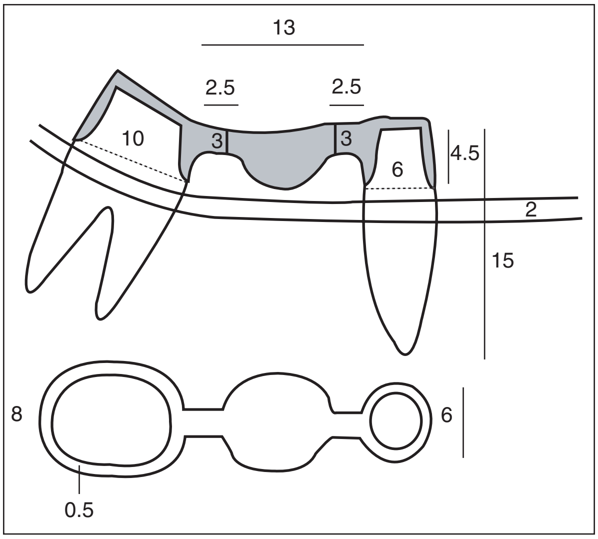
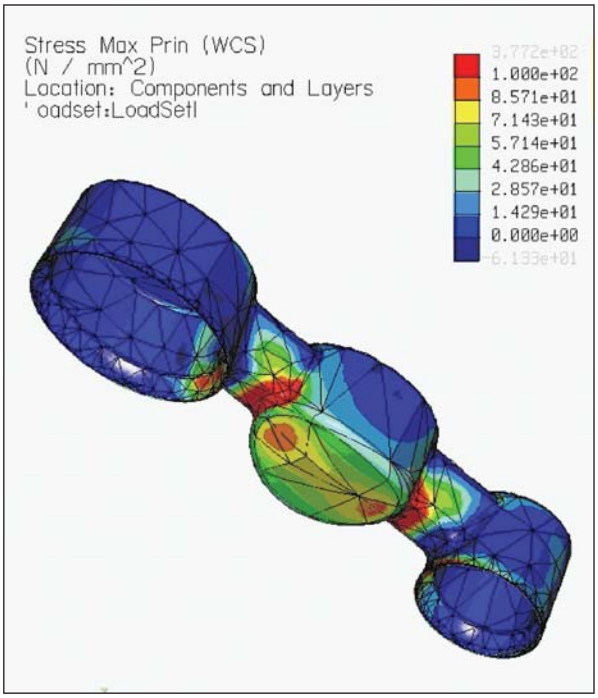


Fig 2 *(right)* Schematic drawing of the curved FPD with the roots of the distal abutment at an angle of 30 degrees in relation to the mesial abutment. The dimensions of the straight and curved dentures are identical. All measurements are in millimeters.

Table 1 Stresses (MPa) in 3-Dimensional Straight and Curved Models

	Measurement point							
Model	1	2	3	4	5	6	7	8
Molar, 0 deg, straight								
With PDL, r = 0.25	121	9	219	855	648	198	15	52
With PDL, r = 0.5	136	29	215	598	522	72	32	53
No PDL, r = 0.25	33	37	6	487	480	4	64	31
No PDL, r = 0.5	32	47	14	377	354	4	61	30
Molar, 30 deg, curved								
With PDL, r = 0.25	91	22	338	1157	793	150	17	63
With PDL, r = 0.5	93	62	345	901	605	149	7	65

Measurement points are numbered according to Fig 2.



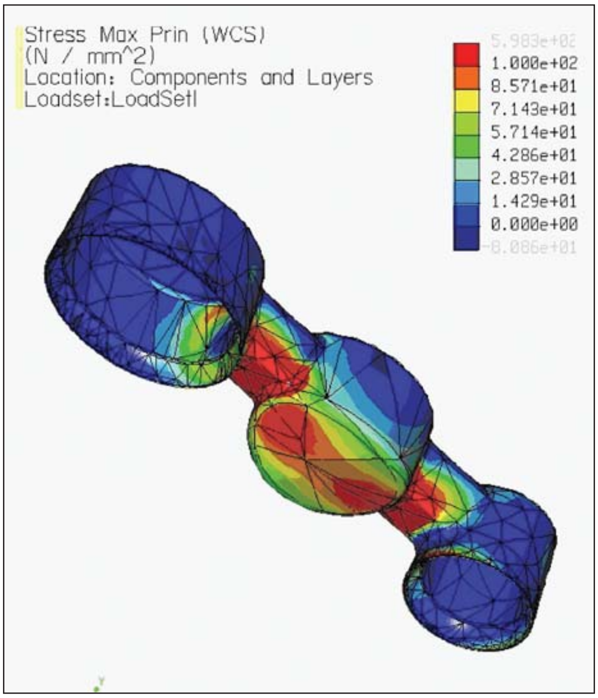


Fig 3 Stresses in the model without *(left)* and with *(right)* a PDL.

the distal connector by 50% to 65% compared to the straight model. The curved model demonstrated higher stresses in the distal abutment core, close to the connector. The high-stress areas inside the distal abutment core were more extensive in the curved model than in the straight model.

Discussion

In this investigation it was postulated that all imitated materials were elastic, homogeneous, and isotropic. The model configurations were constructed with a PDL, simulating a tooth-supported FPD, and without a PDL, simulating an implant-supported FPD. The finding that implant-supported FPDs had significantly lower stresses in the connector area may mean that it is possible to design thinner connectors. A radius of 0.25 mm in the lower connector contact to the core resulted in higher stresses than the radius of 0.5 mm. The curve-shaped model demonstrated much higher stresses in the distal connector. The clinical implication was that this form of an all-ceramic 3-unit FPD gives reason to be aware of the dimensions of the distal connection. It can be concluded that occlusal curvature and the radius of curvature at the embrasure area affect the stress distribution patterns in the connector area of 3-unit FPDs. Critical stresses were significantly lower in simulated implant-supported models than in tooth-supported models.

References

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