Root Fracture of Abutment Teeth for Partial Removable Dental Prostheses

Yoko Mizuno, DDS, PhD1/Tomoya Gonda, DDS, PhD2/Toshihito Takahashi, DDS, PhD3/Akiko Tomita, DDS, PhD4/Yoshinobu Maeda, DDS, PhD5

Purpose: Root fracture is a common and serious cause of abutment tooth loss. No studies to date have comprehensively assessed the individual contributions of the factors that increase stress on abutment teeth. The purpose of this study was to analyze the stress distribution in abutment teeth based on a three-dimensional finite element model and to analyze the factors that affect stress distribution. Materials and Methods: Models were generated from the computed tomography data of a single patient, consisting of a mandibular second premolar abutment tooth, bone, residual mucous membrane, and a partial removable dental prosthesis (PRDP). Four models were prepared using different types of endodontic posts and cores. Akers claspers were used for the simulated PRDPs, and a vertical load was applied to the occlusal surface of the PRDPs. Debonding between the post and root was simulated. The Young modulus of the residual ridge was reduced to simulate a poor fit between the denture base and the residual ridge. Stress distribution in the abutment tooth root was observed, and the maximum principal stress was evaluated. Results: The nonmetal post model and the mesial rest model reduced stress concentration in the root. The stress increased in models simulating debonding and poor fit. The results of the multiple linear regression analysis confirmed that debonding and poor fit were significantly associated with root stress. Conclusion: Within the limitations of this study, it is suggested that the bonding integrity of posts and adequate fit of the denture base are important factors affecting the longevity of abutment teeth for PRDPs. Int J Prosthodont 2016;29:461–466. doi: 10.11607/ijp.4327

Root fracture is a common and serious cause of abutment tooth loss. Axelsson et al1 reported that root fracture was the main cause of tooth loss in patients who maintained a plaque control program. The incidence of root fracture is significantly higher in abutment teeth for partial removable dental prostheses (PRDPs) than in nonabutment teeth, presumably because of the increased loading received by abutment teeth. It is believed that root fracture occurs more frequently in endodontically treated teeth because of the associated loss of tooth structure. Furthermore, root fracture occurs in areas of high stress concentration. The factors that impose stress on teeth, such as the type of post, core,3−7 and denture clasp8−10 used, have been identified, but no studies to date have comprehensively evaluated the individual contributions of these factors.

The purpose of this study was to analyze the stress distribution in abutment teeth based on a three-dimensional finite element model (3D-FEM) and to analyze the factors influencing stress distribution in abutment tooth roots.

Materials and Methods

A single patient at the Osaka University Dental Hospital, who was missing the distal extension on both the left and right sides of the mandible, was selected to participate in this study. The right side was selected for generation of the model. The study protocol was approved by the Ethical Committee of Osaka University Dental Hospital, Japan.
University Graduate School of Dentistry (H24-E13), and informed consent was obtained from the participant after the aims and methodology of the study were explained.

The participant planned to have implant treatment and had undergone a computed tomography (CT) examination. 3D-FEMs were generated using the CT data of the patient and 3D analysis software (Mechanical Finder version 6.1 Extended Edition, Research Center of Computational Mechanics). Models of the mandibular right second premolar, bone, residual mucous membrane, and PRDP were prepared (Fig 1a).

Models of four types of endodontic posts and cores (cast metal post and core, composite resin post and core, composite resin core with a fiber post, and composite resin core with a metal post) for the second premolar were generated (Fig 1b). The diameter of the post was one-third the diameter of the root, and the length of the post was two-thirds the length of the root. The two simulated PRDPs had Akers clasps with either a distal or a mesial rest retained on the abutment tooth (Fig 1c). Material properties for each unit were set according to previous studies, except for bone, which was set using Keyak formula13 (Table 1). The models were constrained on the inferior aspect of the body of the mandible, and adjacent elements were connected rigidly except for the clasp and abutment tooth.

A vertical load of 98 N was applied to the occlusal surface at the first molar position on the PRDP. The models were then analyzed using the 3D finite element analysis software to compare the maximum values of the principal stress within the root.

With long-term denture use, cement dissolution or secondary caries can occur between the post and root, and this was simulated in the present study by debonding between the post and root. The degree of debonding was classified as adequate bonding, debonding only in the mesial cervical area, debonding only in the cervical area, or complete debonding. Additionally, the residual ridge remodels and atrophies over time, which may result in poor fit of the denture base. The Young modulus of the residual ridge was gradually reduced, as follows, to simulate a poor fit between the denture base and residual ridge: 10 MPa, 5 MPa, 1 MPa, 0.1 MPa, and 0.01 MPa.

The models were created with Akers clasps with either a distal or a mesial rest. The distal rest models had 623,033 quadrilateral elements with 119,555 nodes, while the mesial rest models had 637,776 quadrilateral elements with 121,739 nodes. Stress distribution in the root was observed, and the maximum principal stresses were compared.

Multiple linear regression analysis was conducted to reveal the relationship between the maximum value of the maximum principal stress in the root and the variables that may affect stress distribution within the root, including type of endodontic post, type of clasp, debonding between the post and root, and poor fit between the denture base and the residual ridge. A statistical analysis program (Stata 11, Stata) was used to manage and analyze the data with a threshold significance of $P < .05$ for multiple linear regression.
analysis. In the mesial cervical debonding model and the cervical debonding model, the results of the stress analysis with a well-fitting denture base (10 MPa) were included in the multiple linear regression analysis. In the models simulating poor fit (5 MPa, 1 MPa, and 0.1 MPa), the results of the stress analysis in the adequate bonding model were included in the multiple linear regression analysis.

**Fig 2** Maximum principal stress distribution in the abutment tooth root. (a) Stress distribution in the root for each type of post and core (Akers clasp with a distal rest): M = cast metal post and core; R = composite resin post and core; FR = composite resin core with a fiber post; MR = composite resin core with a metal post. (b) Stress distribution in the root for each type of clasp (cast metal post and core model): AD = Akers clasp with a distal rest; AM = Akers clasp with a mesial rest. (c) Changes in stress distribution in the root with debonding between the post and root (cast metal post and core and Akers clasp with a distal rest): AB = adequate bonding; MC = debonding only in the mesial cervical area; C = debonding only in the cervical area; CD = complete debonding. Yellow line = region of debonding. (d) Changes in stress distribution in the root with a poor fit between the denture base and the residual ridge (cast metal post and core and Akers clasp with a distal rest).

**Results**

Stress concentration was observed in the mesial cervical area and the mesial coronal third of the root surface in the abutment tooth with a cast metal post and core. In the models with other types of post, stress concentration was observed in the mesial cervical area (Fig 2a). There was similar stress distribution in models with both mesial and distal rest Akers clasps (Fig 2b). The maximum principal stresses in the mesial coronal third of the root were compared. In the distal rest model, the maximum principal stress was lower in the resin core with a fiber post and the resin post and core than in
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The stress in the root of the mesial rest model was more evenly distributed than in the distal rest model (Fig 2b). The maximum principal stresses in the mesial coronal third of the root surface were compared. Regardless of the type of post and core used, the stress in the root of the mesial rest model was lower than in the distal rest model (Fig 3c).

In the models with a cast metal post and core and a distal rest clasp, the stress distribution varied greatly according to the degree of debonding. In the adequate bonding model, a high-stress area was observed around the mesial cervical area and the mesial coronal third of the root surface. Additionally, a high-stress area was observed in the mesial internal surface of the root in the mesial cervical debonding model and the cervical debonding model. In the complete debonding model, a high-stress area was found around the apex of the post (Fig 2c). The maximum stress observed in the cervical debonding and complete debonding models was greater than the stress observed in the adequate bonding and mesial cervical debonding models (Fig 3d).

In all models, the maximum stress in the root increased as the Young modulus of the residual ridge decreased—that is, where there was a poor fit between the denture base and the residual ridge (Figs 2d, 3e, and 3f).

The results of the multiple linear regression analysis revealed that debonding and poor fit were significantly associated with maximum principal stress in the root (Table 2). The standardized partial regression coefficient of debonding was 0.55, and that of poor denture base fit was 0.78.

Discussion

Fractures occur because of crack initiation and propagation from areas of high stress concentration. Hayashi et al reported that fractures closer to the root apex are more likely to result in extraction. The results of the present study show that because of the high stress concentration in the mesial coronal third of the root surface of the model with a metal post and core, an abutment tooth with a metal post and core is more likely to fracture near the apex of the root and result in extraction than one restored with a resin post and core.

Previous studies reported a reduction in the stress intensity within the root of an abutment tooth with a mesial rest versus a distal rest. These studies did not address stress in nonvital abutment teeth restored with a post and core; however, the findings of the present analysis of nonvital abutment teeth are consistent with the previous studies. This could be because the
distance from the point of load to the center of rotation of the abutment tooth is shorter in the distal rest model than in the mesial rest model.

Clinically, it is difficult to achieve complete bonding between the post and the root. In this study, an area of high stress was found in the mesial cervical area in the case of bonding between the post and root. Crack initiation may occur in this area, which could cause microleakage and cement dissolution. Complete debonding of a rigid metal post and core could produce an area of high stress concentration in the root around the apical portion of the post and core.

There were some limitations to this study. The models were generated with CT data from only a single patient. In future research, models should be generated and analyzed from patients with various types of residual ridges. The residual ridge has viscoelastic properties; however, the FEM software used in this study cannot analyze viscoelastic characteristics and therefore the results were assessed using linear analysis. Post length, diameter, and taper influence stress distribution within the root. Different types of posts should be compared in future studies. Conventional Akers clasps were selected for this study, and the effects of different rest positions were compared. Additional research should be undertaken using different types of retainers.

The results of the multiple linear regression analysis showed that debonding between the post and the root and a poor fit between the denture base and the residual ridge were significantly associated with the maximum principal stress in the root. These findings suggest that examination of the bonding of the post and prevention of secondary caries are important factors in the longevity of PRDPs. It is also important to examine the fit of the denture and reline the denture base if necessary. No significant differences in stress in the root depending on the type of post or clasp were found in the multiple linear regression analysis; however, the results of the stress analysis suggest that root fracture can be prevented by carefully considering the denture design and the type of endodontic post used to restore abutment teeth.

### Conclusions

Within the limitations of this study, it was concluded that nonmetal posts reduce stress concentration in the abutment teeth of PRDPs. The stress in the root of the mesial rest model was lower than in the distal rest model. Debonding between the post and the root and poor fit between the denture base and the residual ridge also increased stress in the abutment tooth root. The results of the multiple linear regression analysis confirm that debonding and poor fit were significantly associated with stress in the root. Other variations should be analyzed in future studies.

### Table 2  Multiple Linear Regression Analysis (n = 72)

<table>
<thead>
<tr>
<th></th>
<th>Partial regression coefficient</th>
<th>Standardized partial regression coefficient</th>
<th>P</th>
<th>Collinearity VIF</th>
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<td>Endodontic post</td>
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<td></td>
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<td>R</td>
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<td>.21</td>
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<td>FR</td>
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<td>0.08</td>
<td>.27</td>
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<tr>
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<td>1.00</td>
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<td>(4)</td>
<td>294.7</td>
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<tr>
<td>Changes in fit between denture base and residual ridge</td>
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<td>5 MPa</td>
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<td>1 MPa</td>
<td>154.5</td>
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<td>0.01 MPa</td>
<td>421.8</td>
<td>0.78*</td>
<td>.00</td>
<td>1.56</td>
</tr>
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</table>

Objective variable: highest maximum principal stress (MPa).
Explanatory variables:
Type of endodontic post (standard = cast metal post and core): R = composite resin post and core; FR = composite resin core with a fiber post; MR = composite resin core with a metal post.
Type of clasp: Akers clasp with a distal rest = 0, Akers clasp with a mesial rest = 1
Fit between denture base and residual ridge (standard = Young modulus of the residual ridge): 10 MPa = satisfactory fit.
Adjusted $R^2 = 0.75$.

$^*P < .05.$
Acknowledgments

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References


Literature Abstract

A Detailed Analysis of Mandibular Angle Fractures: Epidemiology, Patterns, Treatments, and Outcomes

This useful retrospective study aims to determine the relationship between treatment modality patient outcomes. Mandibular angle fractures are common and have high complication rates, and the ideal treatment modality is unclear. A total of 103 patients (mean age: 30.4 years) treated by the same operator were included. Three treatment variables (fixation type, use of IMF, and teeth in the fracture line extracted or not) and three patient outcomes (postoperative infection, fracture healing, and patient comfort) were examined. The vast majority of patients were men who had suffered a physical injury to the left side of the jaw in the month of June. The Champy plate and two-plate technique resulted in 100% bony union. Use of IMF or presence of teeth in the fracture line had no statistically significant effect on infection, healing, or comfort. The strut or ladder technique closely followed by the Champy plate was most comfortable. The authors admit that the low numbers, retrospective design, and effect of confounding factors such as smoking habits are weaknesses in this study. However, this is useful guidance to supplement the surgeon’s experience.


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