# Abutment load transfer by removable partial denture obturator frameworks in different acquired maxillary defects

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**Statement of problem.** Excessive stress on abutment teeth adjacent to a maxillary resection defect during loading of partial denture obturator frameworks may shorten the life of the teeth.

**Purpose.** The aim of this study was to photoelastically compare the forces exerted on the supporting structures of abutment teeth in 3 differently sized surgical resections with removable partial denture designs used to restore such maxillectomy defects.

**Material and methods.** Composite photoelastic models were constructed of a human maxilla that had undergone each of 3 maxillectomies: partial, radical, and radical involving the contralateral premaxilla. The abutment teeth included all remaining anterior teeth, the first premolar, and second molar, except the radical maxillectomy, which included the contralateral premaxilla where all remaining teeth were used as abutment teeth. All abutment teeth were restored with complete metal crowns, and removable partial denture frameworks were fabricated. Loading zones were selected according to the resection, and a 10-lb load was applied at each load point. The resulting stresses were observed and recorded photographically in a circular polariscope. The 2 teeth adjacent to the resection were then splinted, and the loading regimens were repeated.

**Results.** Without splinting, loads closer to the defect produced lingual tipping of the teeth adjacent to the resection and a mesial tipping tendency of the second molar. The tipping effects were greatest in the model with the largest resection. Splinting reduced tipping of the teeth adjacent to the resection and produced more uniform stress around these 2 abutment tooth roots for all of the models.

**Conclusion.** The results of this in vitro study suggest that splinting the 2 teeth adjacent to a resection defect improves stress distribution around the roots during loading. This could increase the clinical life of the abutment teeth. (J Prosthet Dent 2005;94:281-8.)

**CLINICAL IMPLICATIONS**

*Splinting the 2 anterior teeth adjacent to a maxillary resection defect may produce improved functional stress distribution to the supporting periodontal structures and prolong the life of these teeth.*

Surgical resection of tumors of the maxilla and paranasal sinuses results in loss of structures, including the teeth and bone. Following such resections, the support, retention, and stability of the removable partial denture (RPD) acting as an obturator depends on the remaining hard and soft tissues. Since forces are transmitted to abutment teeth by rests, guide planes, and retainers, the RPD framework design should be made in anticipation of the movements that will occur with the prosthesis during function. The objective of the framework design, then, should be to preserve the remaining structures. The larger a surgical resection, the greater the loss of support and, therefore, the higher the unfavorable forces acting on the remaining teeth.[1-3] Although the framework design will vary according to the size of the resection, the design objectives remain the same: to distribute or control the functional forces so that each supporting or retaining element can be used to maximum effectiveness without being stressed beyond its physiological limits.[3-8] These objectives are best achieved with a quadrilateral or tripodal design rather than a linear design, as this allows a more favorable distribution of functional forces.[6,7] In addition, the design of the partial denture should be based on general principles. This includes a rigid major connector, occlusal rests to direct occlusal forces down the long axis of the teeth, guide planes to facilitate stability, and bracing and retention

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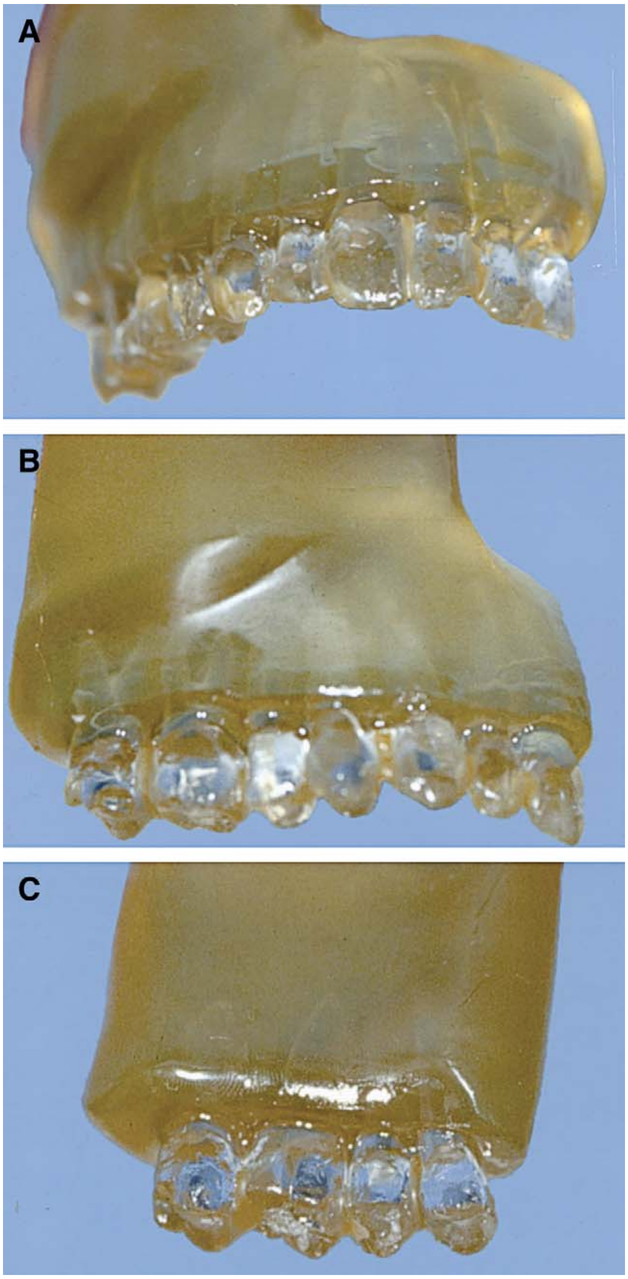


**Fig. 1.** Composite photoelastic models of different maxillary defects arranged according to size of resection defect. **A,** Model 1 (Aramany Class 2 resection defect), partial maxillectomy retaining all anterior teeth and posterior teeth on nondefect side. **B,** Model 2 (Aramany Class 1 resection defect), total maxillectomy extends length of midpalate to mesial surface of central incisor. **C,** Model 3 (Aramany Class 4 resection defect), total maxillectomy involving contralateral premaxilla.

that do not exceed the physiological limits of the periodontal ligament.[9,10] When designing the anterior rests for the partial denture framework, cingulum rests should be used with anterior teeth because they are best able to direct occlusal forces down the long access of the tooth and will also help prevent displacement of the framework palatally or toward the defect.[5,8] Splinting abutment teeth may also be beneficial. A splint can reduce functional tooth movement by averaging the movement of individual teeth when either the abutment teeth or obturator are subjected to loading.[11]

In vitro studies, such as photoelastic analysis, allow an experimental design limiting both patient and operator variables. Although photoelastic analysis has inherent limitations with respect to its capacity to model the nonhomogenous and anisotropic characteristics of teeth, bone, and periodontal ligament, the technique has been extensively and successfully used in dentistry to study the interaction of tissue response and physical characteristics of prosthetic restorations.[4,5] The occlusal force transfer by RPD designs for a radical maxillectomy has been documented,[5] but the influence of loading partial denture obturator frameworks restoring various sized maxillary resection defects on the stress distribution of abutment teeth has not been sufficiently assessed. The purpose of this study was to photoelastically compare and evaluate the forces exerted on the supporting structures of abutment teeth in 3 differently sized surgical resections by loading an appropriate RPD used to restore such maxillectomy defects.

## MATERIAL AND METHODS

Composite photoelastic models were constructed of a human maxilla that simulated 3 different acquired maxillary defects commonly seen in the maxillectomy patient. The 3 maxillary defects, which were ordered by size of the resection defect from smallest to largest and classified according to Aramany,[1] were as follows: Model 1 (Aramany Class 2) partial, in which all 6 anterior teeth remained along with the posterior teeth on the nondefect side (Fig. 1, *A*); Model 2 (Aramany Class I) total maxillectomy, in which the defect extended the length of the midpalate to the mesial surface of the central incisor (Fig. 1, *B*); and Model 3 (Aramany Class 4) total maxillectomy, involving the contralateral premaxilla in which the only remaining dental support was from the first premolar to the second molar on one side (Fig. 1, *C*). Individual photoelastic materials were used to simulate teeth (PLM-1; Measurements Group Inc, Raleigh, NC), periodontal ligament (Solithane; Uniroyal Chemical Company Co, Middlebury, Conn), and bone (PL-2; Measurements Group Inc).

The teeth and roots were of average size.[12] The crowns of the abutment teeth were prepared, waxed, and cast for complete metal crowns. The teeth were prepared by one person and standardized by cutting uniform vertical and horizontal grooves 0.5 mm deep into each tooth using laminate veneer diamond depth guides (Brasseler Laminate Veneer System; Brasseler, Berlin, Germany), and a 0.5-mm shoulder margin

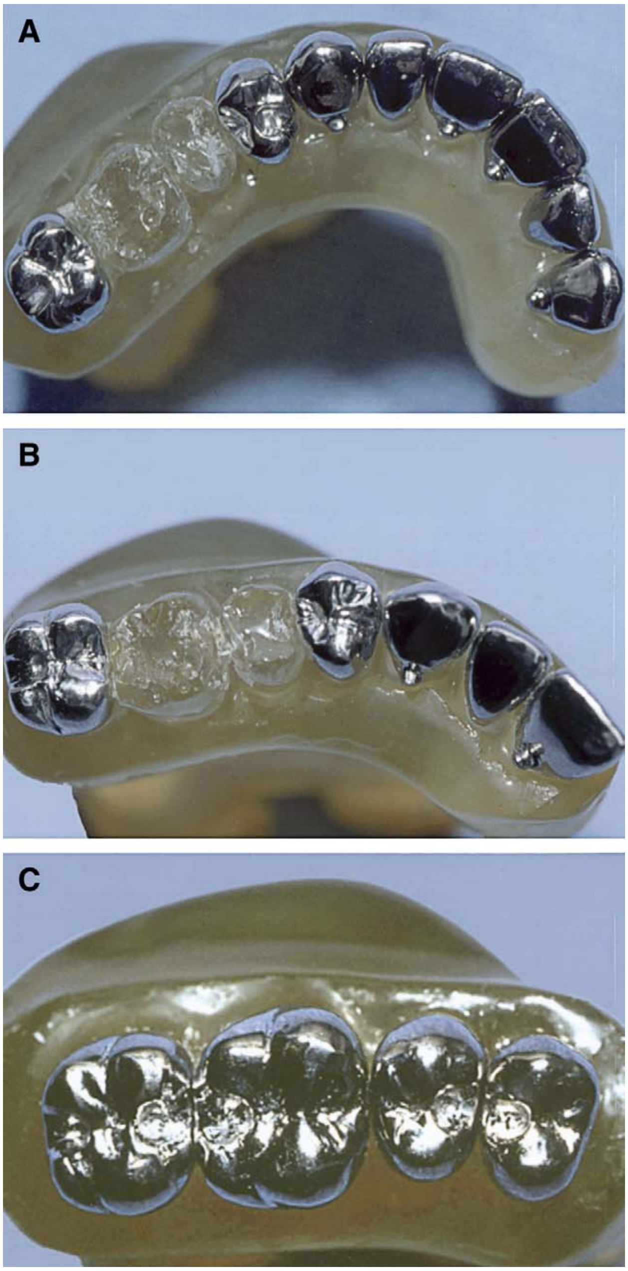


**Fig. 2.** Cast metal crowns cemented in place on models illustrating partial denture rest seat positions. **A,** Model 1. **B,** Model 2. **C,** Model 3.

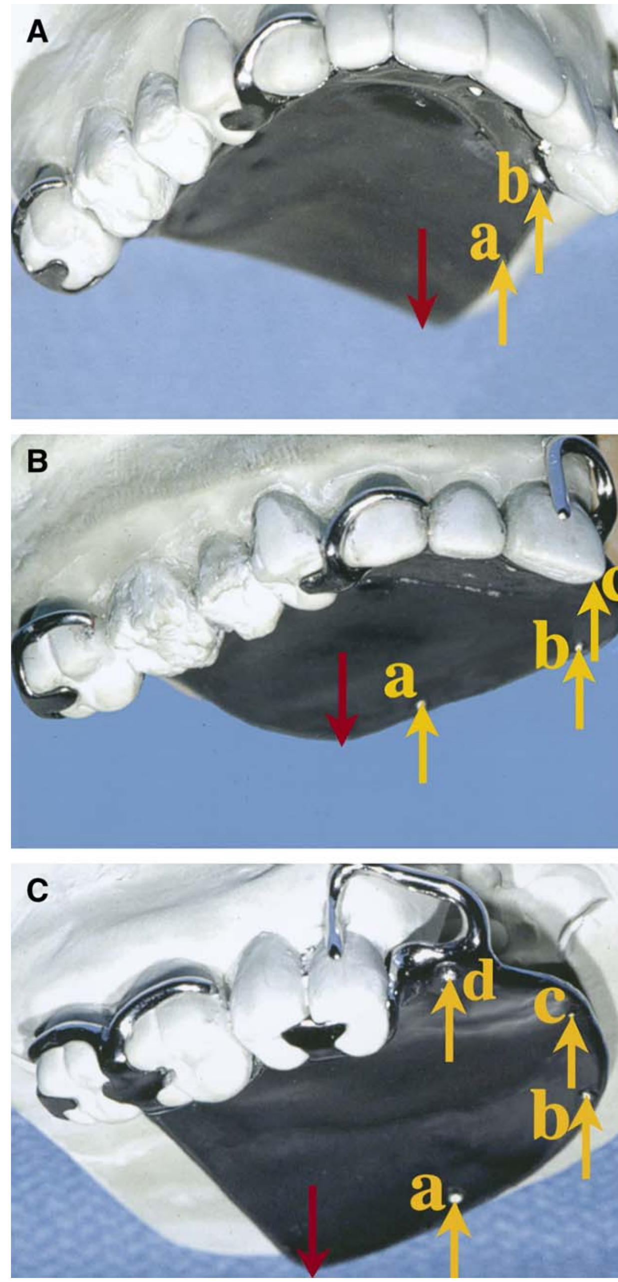


**Fig. 3.** Partial dentures on casts illustrating denture designs and simulated occlusal loading points marked *a, b, c,* and *d* (*yellow arrows*) and gravity forces (*red arrows*). **A,** Model 1. **B,** Model 2**. C,** Model 3.

preparation was prepared. Preparation for complete coverage cast crowns was completed using a water-cooled high-speed straight medium diamond rotary cutting instrument (# 837KR; Komet, Berlin, Germany). The shoulder of the preparations followed the cementoenamel junction. An addition silicone (Exaflex; GC America, Alsip, Ill) impression was made, from which a Type V die stone (Die-Keen Green; Heraeus Kulzer, Armonk, NY) cast of each maxillary defect was made. Three layers of die spacer (Tru-Fit; George Taub Products and Fusion Co Inc, Jersey City, NJ) were placed over the crown preparations, after which molten wax (Plastodent-Set; Degussa Dental, Frankfurt, Germany) was poured over the crown preparation. The wax coping was refined, sprued, and vacuum invested in a gypsum-bonded investment material (Hi-Temp; Whip Mix Corp, Louisville, Ky). Metal castings were subsequently made from a gold-palladium-gallium alloy containing 2.0% gold, 79.0% palladium, and 9.0% gallium (Spartan Plus; Ivoclar Vivadent, Schaan, Liechtenstein).

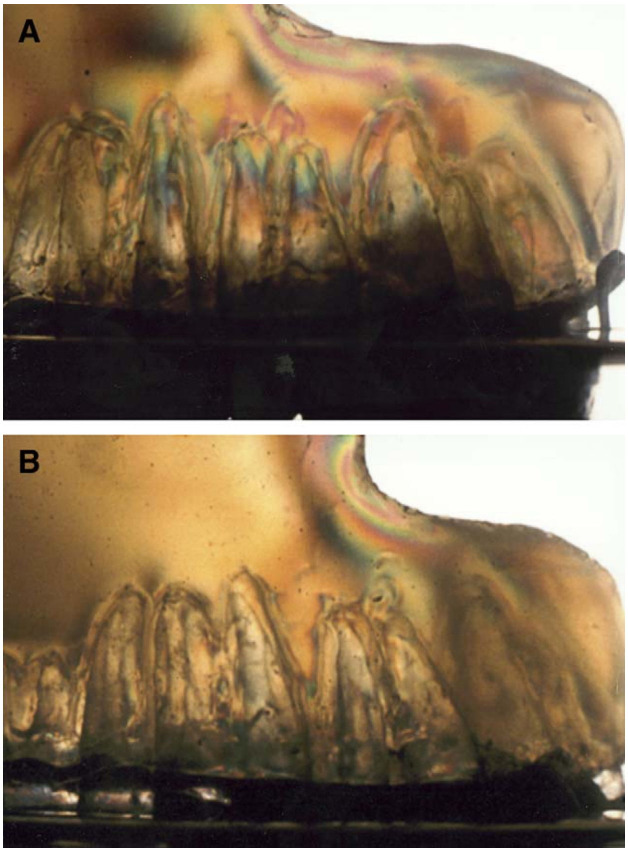


**Fig. 4.** Stresses developed in Model 1. **A,** Load at point *b*, unsplinted condition. **B,** Load at point *b*, splinted condition.

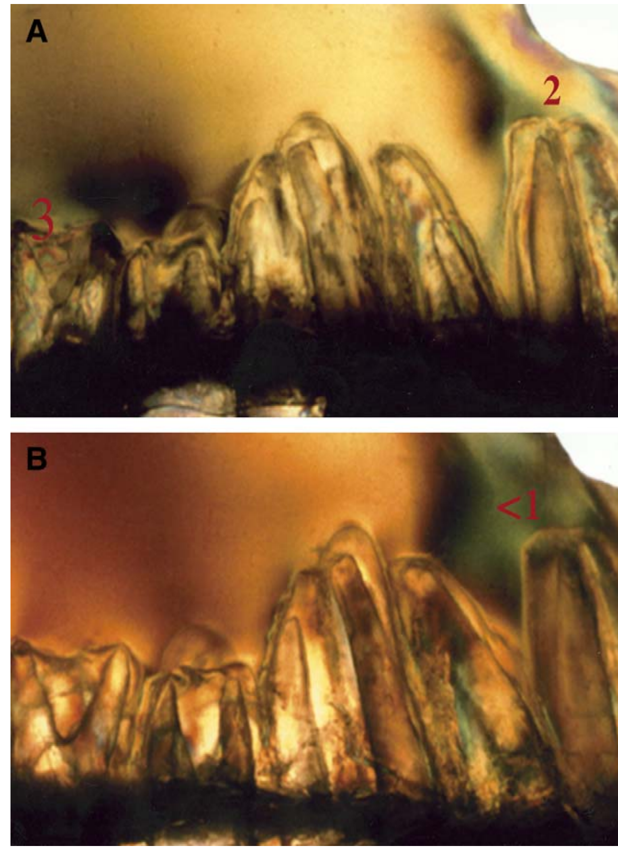


**Fig. 5.** Stresses developed in Model 2. **A,** Load at point *c*, unsplinted condition, 2 fringes maximum. **B,** Load at point *c*, splinted condition, >1 fringes maximum.

The crowns were cemented in place on the photoelastic models using zinc phosphate cement (S.S. White Manufacturing Ltd, Gloucester, England). Figure 2 shows the crowns on the models and illustrates the position of rest seats described below.

Removable partial denture frameworks were fabricated from chrome-cobalt alloy (Wironit; Bego, Bremen, Germany) with extension bases extending into the defect. The framework designs included: (1) positive cingulum rest seats on anterior abutments, conventional occlusal rest seats on posterior teeth; (2) an I-bar retainer on the tooth immediately adjacent to the simulated resection; (3) buccal and lingual retainers; and (4) retentive undercuts of 0.25 mm. The designs for the 3 resections were as follows: Model 1 (Aramany Class 2 resection defect): A buccal circumferential cast retainer and a distal rest seat on the maxillary right second molar, a mesial rest seat on the maxillary right first premolar, a buccal circumferential cast retainer and a cingulum rest seat on the maxillary right canine, and an I-bar retainer and cingulum rest seat on the maxillary left canine (Fig. 3, *A*); Model 2 (Aramany Class 1 resection defect): A buccal circumferential cast retainer and distal rest seat on the maxillary right second molar, a mesial rest seat on the maxillary right first premolar, a buccal circumferential cast retainer and cingulum rest seat on the maxillary right canine, and an I-bar retainer and cingulum rest seat on the maxillary right central incisor (Fig. 3, *B*); and Model 3 (Aramany Class 4 resection defect): A buccal circumferential cast retainer and mesial and distal rest seat on the maxillary right second molar, a buccal circumferential cast retainer and distal rest seat on the maxillary right first molar, a mesial rest seat on the maxillary right second premolar, and an I-bar retainer and distal rest seat on the maxillary right first premolar (Fig. 3, *C*).

All RPD designs had lingual plating on all teeth and a major connector extending into the defect so that occlusal loads could be transmitted to the cast. The partial denture base for all designs was made to extend into the defect to facilitate load transmission to the model. A load of 10 lbs was applied at each load point,[5] and loading zones were selected according to the simulated resection (Fig. 3, *A-C*). Loads were applied in a straining frame by a calibrated load cell and monitored with a digital read-out (Model 2130 and 2120A; Measurements Group Inc). The effect of gravity was then tested by applying a 0.2-lb force to the palatal ex-

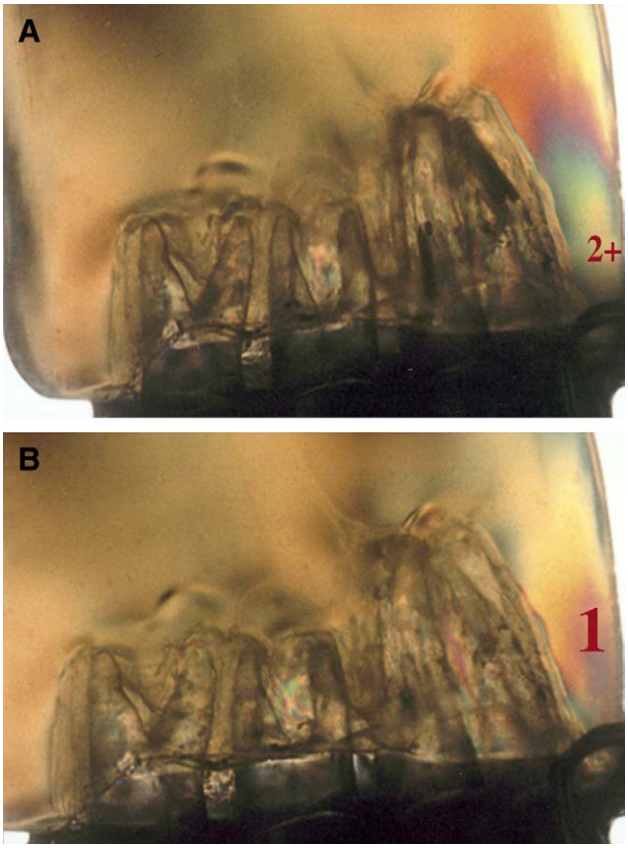


**Fig. 6.** Stresses developed in Model 3. **A,** Load at point *d*, unsplinted condition, 2 fringes maximum. **B,** Load at point *d*, splinted condition, 1 fringe maximum.

tensions of the frameworks to correspond to the weight of an obturator.[13] The force was applied by attaching the partial denture framework to the load cell and applying an upward vertical force. The 2 teeth adjacent to the resection were then splinted together by soldering and the loading regimens were repeated. All loading was performed with the models immersed in a tank of mineral oil to minimize surface refraction and thereby facilitate photoelastic observation. Resulting stresses were recorded photographically in the field of a circular polariscope (Measurements Group Inc).

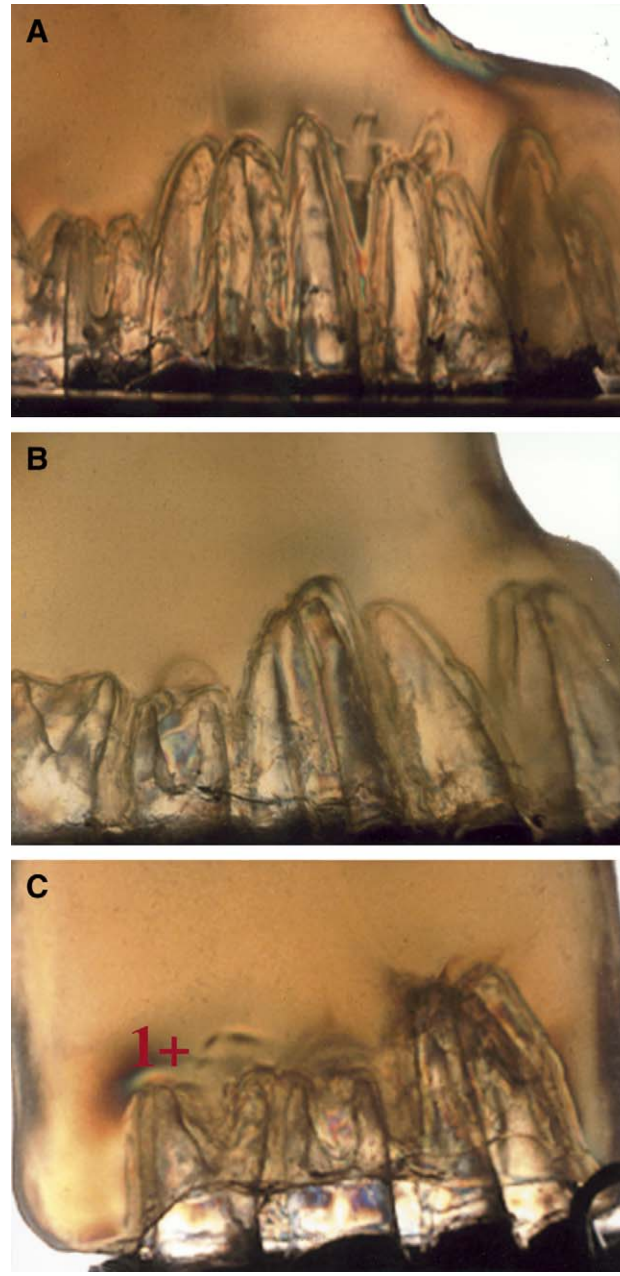


**Fig. 7.** Stresses developed under simulated gravity forces. **A,** Model 1, no fringes. **B,** Model 2, no fringes. **C,** Model 3, 1 fringe order.

## RESULTS

### Model 1 (Aramany Class 2 resection defect)

For the unsplinted condition, load applied between the central and lateral incisor on the resection side (point *a*) caused lingual tipping of teeth adjacent to the resection and some mesial tipping of the molars (Fig. 4, *A*). Splinting of the teeth adjacent to the resection produced a marked reduction of stress intensity and tipping of the teeth (Fig. 4, *B*). With the load applied adjacent to the canine on the resection side (point *b*), lower stresses and tipping tendency occurred for both the splinted and unsplinted conditions (Fig. 4, *C*).

### Model 2 (Aramany Class 1 resection defect)

In the unsplinted model, load points closer to the defect produced more lingual tipping of the 2 teeth adjacent to the resection, as well as a mesial tipping tendency of the second molar (Fig. 5, *A*). For loads further from the teeth, there was a greater tipping action on the canine and first premolar, as well as more tipping of the molars. Following splinting, there was a reduction in tipping of the teeth adjacent to the resection for all of the load positions and a more uniform distribution of stress around the roots (Fig. 5, *B*).

### Model 3 (Aramany Class 4 resection defect)

Loads near the resection tended to cause lingual tipping of teeth adjacent to the resection and mesial tipping of molars (Fig. 6, *A*). Higher loads (10 lbs) caused instability of the framework. However, splinting improved framework stability. Splinting of 2 teeth adjacent to the defect reduced tipping of the teeth and generally lowered stress intensities with more uniform distribution (Fig. 6, *B*).

### Simulated gravity

Simulated gravity produced only minor effects on the teeth for all models (Fig. 7, *A* through *C*). However, slightly higher stresses were noted, primarily at the distal apex of the second molar, in the model with the largest defect.

## DISCUSSION

The limitation of homogenous, isotropic photoelastic models is their inability to perfectly model the biologic structures they are intended to replicate. This is because of the inherent limitation of modeling the nonhomogenous and anisotropic characteristics of teeth, bone, and periodontal ligament using various resins. Photoelastic models do not consider, for example, the differentiation of cortical and medullary bone. This method does, however, have the advantage that it allows stresses throughout a complexly shaped model to be observed, thereby facilitating the location and magnitude of stress concentrations. Despite the limitations of photoelastic models, this technique has been extensively and successfully used in dentistry to study the interaction of tissue response and physical characteristics of prosthetic restorations, while at the same time allowing an experimental design that limits both patient and operator variables.

The prognosis of a satisfactory prosthodontic outcome for the dentate patient with a maxillectomy defect improves with the availability of teeth to assist with the retention, support, and stability of the RPD.[7] Other than the teeth, the location of the defect, length of the lever arm, and arch form are factors that should be considered when designing the RPD.[1-3,5-7] Standardization was achieved in this study by using the same master model for each of the simulated resections, and partial denture designs were based on general principles.[9,10] Multiple rests were used to improve stability and support for the prosthesis, and complete crowns were placed on all abutment teeth to establish ideal contours for retention, guide planes, and occlusal rests. Although the RPD frameworks were not identical, each of the 3 designs had the same features. Each had a rest on the tooth adjacent to the resection and on the most distal tooth, guide planes were placed anteriorly and posteriorly, buccal rather than palatal retention was used, and each had an I-bar retainer on the most anterior tooth. The use of the I-bar retainer with a cingulum rest seat has been previously shown to provide the best combination for transmitting occlusal forces along the long axis of the tooth in the anterior region.[5] The remaining rests and the major connector were designed to provide support, retention, and stability appropriate for the particular resection concerned.

Teeth adjacent to the anterior margin of the defect should have a positive rest seat and retainer for adequate retention.[3,5,6] The anterior rest seat and retainer also ensure proper orientation of the prosthesis and help prevent rotation of the prosthesis out of retentive areas posteriorly. While palatal support provided by an obturator will very likely change the force distribution during functional loading depending on the amount of palate retained following resection surgery, no palatal support was present in this study so that the forces transmitted to the abutment teeth by the rests, guide planes, and retainers during loading could be evaluated.[5,13] This and previous studies have shown that the anterior abutments are subject to greater vertical and lateral forces,[5] and are more frequently lost than abutments in other positions.[8] This is due to a number of factors. The extension area adjacent to this abutment is the defect, which provides little support, and the lever arm can be very long, increasing the forces applied to the abutment tooth.[3,7] These effects were seen in this study. When the load points were close to the anterior margin of the defect, there was a high degree of tipping of the 2 teeth adjacent to the resection, indicating potentially destructive lateral torquing forces during function. Although these forces were distributed to the remaining abutment teeth as the load point moved away from the abutment tooth adjacent to the resection defect, most of the forces remained around the teeth adjacent to the defect. In addition, the tipping action on these teeth increased considerably as the applied load was increased. This is not unexpected, as the distribution of forces to the abutment teeth and the torquing action of the partial denture framework increase with increased loading.

The axis of rotation, or the fulcrum line, is also influenced by the size of the resection, which changes as the resection size increases. The larger a defect, the greater the number of axes.[8] The teeth are also more likely to be in a linear or straight line, so that the fulcrum line will be the same as the tooth alignment.[6] This results in a tendency for greater movement around the fulcrum line under function, which was seen in this study, where the tipping effects were greatest in the model with the largest resection. This demonstrates the importance of saving as many teeth as possible and as much of the premaxillary segment on the resection side. Salvaging the premaxilla within the limitations of tumor removal will reduce damaging functional stress transfer to the tooth roots. In addition, changing the arch form to a square or tapering form creates less of a linear arrangement of the dentition, improves the location of the fulcrum line, and increases the effectiveness of the indirect retainers.[3,6,7] Although this was considered in the RPD design for the larger defect, in which more retention was provided along with bracing from multiple retainers as recommended by Aramany[6] and Parr et al,[3] the effect of the reduced number of abutments was demonstrated in this study. For example, the 10-lb load regimen was selected based on a previous study.[5] While Schwartzman[13] used a 12-lb load, a 10-lb load was selected in this study because this was the maximal load that could be applied to Model 3 (Aramany class 4 model) without displacement of the partial denture framework from the model during loading.

Larger defects will also be restored with a prosthesis that is both heavier and less stable, resulting in more movement when subjected to the forces of mastication. With heavier prostheses, gravitational forces are more of a concern. In this study, the effects of simulated gravity produced only minor effects on the teeth, but were slightly higher in the model with the largest defect. The defects, however, were not restored with an obturator, and clinically, the effect of gravity on the abutments seen in this and a previous study[13] is likely to be greater. Schwartzman[13] also showed that, under gravity-induced stresses, partial denture frameworks, which used I-bar and circumferential retainers with buccal retention, as in this study, produced fewer effects than other types of retainers.

The load points and the loads used in this study were those considered to be most commonly used in vivo.[5,8] Most patients will function on either the unresected side or at a site adjacent to the resection. Because of the lack of support in the resection defect region, patients rarely apply loads in this area. Consequently, a critical factor regarding the formulation of an RPD design is the position of the rest seat on the most anterior tooth.[5,8] Cingulum rests are best able to direct occlusal forces down the long access of the tooth and will also help prevent displacement of the framework lingually or towards the defect.[5,8] For these reasons, cingulum rests are the recommended rests in the anterior region for these resections. Anterior abutment teeth are lost more frequently than abutments in other locations because of the single-rooted anatomy of these teeth, the loss of bony support following resection, and the greater vertical and lateral forces to which the anterior abutments are subjected.[8] If 1 or more of these teeth are compromised, they should be endodontically treated and the crown should be amputated so that the root can serve as an overdenture abutment.[8] If these teeth are sound, consideration should be given to placing splinted crowns on the anterior 2 abutments.[3,7] Doing so will permit an ideal cingulum rest seat and retainer undercut to be prepared, increasing retention and support of the partial denture framework. It will also change the abutment from a single to a 2-rooted tooth, improving mechanical load transfer to the periodontal ligament and surrounding bone in this compromised clinical situation. This study has shown that splinting the 2 anterior teeth adjacent to the resection reduces tipping of these teeth and produces a more uniform distribution of stress around the roots compared to the same unsplinted teeth. This suggests that providing mutual support to these teeth by splinting is likely to prolong their useful life by reducing the destructive tipping forces. It also appears to improve distribution of stress around the roots of the teeth most at risk of failure. The longer teeth retained after surgical resection are maintained in a healthy condition, the better the retention, support, and stability of the definitive obturator, and the greater the satisfaction of the patient following prosthodontic rehabilitation.

It is important to note that this study considered only the RPD design as a factor of stress transmission to the remaining abutment teeth. However, in vivo, the resection defect and the adjacent anatomic structures may be used for additional support, which would provide more even distribution of stress to the remaining teeth during function. Following resection of the maxilla, the mucosal and bony support is compromised or may be completely lacking, so that the resection defect must be used to minimize movement of the prosthesis. However, the size and usefulness of the surgical defect varies for every situation and so was not simulated in this study. In addition, if forceful mastication occurs on the resection side, the prosthesis can be displaced significantly into the defect, subjecting the abutment teeth to damaging lateral torquing forces. Future clinical studies are needed to demonstrate whether a clinical benefit can be gained by splinting the abutment teeth adjacent to a maxillary resection defect.

## CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. Under load, all of the unsplinted models produced lingual tipping of the 2 teeth adjacent to the resection, as well as a mesial tipping tendency of the second molar. The tipping effects were greatest in the model with the largest resection.
2. Following splinting, there was a reduction in tipping of the teeth adjacent to the resection for all of the models, and a more uniform distribution of stress around the roots.
3. Simulated gravity produced only minor effects on the teeth, but were slightly higher in the model with the largest defect.

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**Noteworthy Abstracts of the Current Literature**

**Long-term treatment costs associated with implant-supported mandibular prostheses in edentulous patients**
Attard NJ, Zarb GA, Laporte A. *Int J Prosthodont* 2005;18:117-23.

**Purpose:** The study's aim was to report long-term costs in edentulous patients treated with mandibular implant-supported prostheses.
**Materials and Methods:** Ninety patients were divided into four groups based on the type of implant prosthesis (fixed or overdenture) and treatment year. Records were obtained from dental charts, and an economic analysis from the patient's perspective was conducted. Clinical time associated with various procedures was measured and applied to the four groups. Salary rates by age, occupation, and gender were used to value patients' time. Direct clinical and time costs over 10 years were converted to 2002 Canadian dollars using the Consumer Price Index and discounted at a 3% rate. A sensitivity analysis at an equal salary rate was carried out to test the robustness of the time costs.
**Results:** Initial treatment and maintenance costs over the observation period were significantly higher for fixed compared to overdenture prostheses. A significant improvement in maintenance costs for the first patient group treated with fixed prostheses was observed over the follow-up period. Longer term (15 years) treatment costs for the initial two groups were significantly higher for the fixed group. The sensitivity analysis at an equal salary rate demonstrated the same trend: Time costs were significantly higher for the fixed groups.
**Conclusion:** Long-term treatment costs indicated that the mandibular overdenture was a less expensive treatment compared to the fixed implant prosthesis.—*Reprinted with permission of Quintessence Publishing.*