Photoelastic Analysis of the Influence of Platform Switching on Stress Distribution in Implants

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The aim of this study was to evaluate the stress distribution of platform switching implants using a photoelastic method. Three models were constructed of the photoelastic resin PL-2, with a single implant and a screw-retained implant-supported prosthesis. These models were Model A, platform 5.0 mm/abutment 4.1 mm; Model B, platform 4.1 mm/abutment 4.1 mm; and Model C, platform 5.00 mm/abutment 5.00 mm. Axial and oblique (45°) loads of 100 N were applied using a Universal Testing Machine (EMIC DL 3000). Images were photographed with a digital camera and visualized with software (AdobePhotoshop) to facilitate the qualitative analysis. The highest stress concentrations were observed at the apical third of the 3 models. With the oblique load, the highest stress concentrations were located at the implant apex, opposite the load application. Stress concentrations decreased in the cervical region of Model A (platform switching), and Models A (platform switching) and C (conventional/wide-diameter) displayed similar stress magnitudes. Finally, Model B (conventional/regular diameter) displayed the highest stress concentrations of the models tested.

Key Words: dental implants, biomechanics, platform switching, photoelastic stress analysis

INTRODUCTION

The final goal of oral rehabilitation with osseointegrated implants is to create an optimal prosthetic restoration surrounded by stable bone, with a natural gingival architecture, ensuring functional and esthetic harmony. The lack of postoperative bone resorption around the implant collar constitutes a vital factor in stabilizing the papillae and obtaining a harmonious dental neck line in relation to neighboring teeth.¹–⁵

Bone resorption around the implant neck is frequently observed after loading and appears to depend on both biological and mechanical factors, such as biological width, bacterial microleakage, location of the inflammatory conjunctival tissue area,⁶–¹⁰ cervical area stress concentration, location of the implant/abutment joint,⁴ and micro-
Some clinical, histological, and retrospective studies have shown that crestal bone loss around dental implants can be prevented by applying platform switching. In a standard protocol, implants are rehabilitated with abutments of the same diameter. The platform switching technique uses prosthetic components that are undersized relative to the diameter of the implant platform.

Mechanical and biological principles of platform switching have been theorized for how bone loss can be minimized. First, with the increased surface area created by the exposed implant seating surface, the amount of crestal bone resorption necessary to expose a minimum amount of implant surface to which the soft tissue can attach is reduced. Second, and perhaps more important, by repositioning the implant-abutment junction (IAJ) inward and away from the outer edge of the implant and adjacent bone, the overall effect of the abutment inflammatory cell infiltrate (ICT) on surrounding tissue may be reduced, thus decreasing the resorptive effect of the abutment ICT on crestal bone. As a consequence, the reduced exposure and confinement of the platform-switched abutment ICT may result in a reduced inflammatory effect within surrounding soft tissue and crestal bone.

The biological benefits and clinical efficacy of the platform switching technique have been demonstrated by numerous studies. However, the biomechanics of this technique have been researched only minimally. Evaluation of the mechanical factors and their influence on bony tissue preservation is of great importance. One method used for such study is photoelasticity, which allows prediction of the mechanical response of a photoelastic model when load is applied. Thus, the aim of this study was to evaluate the stress distribution of platform switching implants using a photoelastic method.

Using a wax block simulating a mandibular bone portion, a mold was constructed using duplication silicone (Sapeco, Bauru, São Paulo, Brazil). This matrix was then poured with dental stone type IV (Durone, Dentsply, Petrópolis, Rio de Janeiro, Brazil). An analogue implant (Conexão Sistemas de Prótese Ltda, Arujá, São Paulo, Brazil) was inserted into the dental stone blocks with a dental surveyor, corrected the seating of the implant (Figure 1) (Conexão Sistemas de Prótese Ltda), and was verified; then another mold was obtained with the implants correctly positioned. The photoelastic resin (PL-2, Vishay, Micro-Measurements Group Inc, Raleigh, NC) was manipulated according to the manufacturer’s instructions. The mold was poured with resin and placed under a pressure of 40 lbf/in² (to remove the internal bubbles), thereby producing 3 photoelastic models (Table).

Three screw-retained implant-supported prostheses (UCLA abutment) were constructed with a nickel/chrome (NiCr) alloy (Figure 2). The crowns were screwed onto the implant of the photoelastic model with a torque of 20 N. Each model was placed in a circular polariscope (Figure 3). Axial (0°) and oblique (45°) loads of 100 N were applied at fixed points on the occlusal surface of all crowns with a Universal Testing Machine (EMIC-DL 3000, São José dos Pinhais, Paraná, Brazil), which was programmed to transmit the load for a period of 10 seconds.

The stress patterns (photoelastic fringes) resulting from force application in the photoelastic models were photographed by a digital camera (Nikon D80, Nikon Corporation, Tokyo, Japan), and subsequently transferred to a computer graphics software (AdobePhotoshop, Adobe Systems, San Jose, Calif) for visualization. For qualitative analysis, the area around each implant was arbitrarily divided into 3 zones, corresponding to the coronal, middle, and apical third of each implant.
Photographic records were analyzed by 2 investigators, who observed and compared stress patterns to determine the relative stress magnitudes and locations. Qualitative analysis followed the method outlined by Caputo and Standlee,19 where the number and proximity of the fringes to each other was proportional to the stress magnitude and concentration, respectively.

**RESULTS**

Before loading, all specimens were free from any stress pattern, such that all stress patterns observed were the direct result of the occlusal load applied to the implants.

**Axial load**

Figures 4, 5, and 6 show that the stress distribution patterns were similar for all models, with stress concentration at the middle to apical third, and the highest stress concentrations were at the apical level. In Models B and C, stress was concentrated from the middle third to the apical portion of the implant, but in Model A (Figure 4), the stress was more centralized at the apical area. Stress concentration at the coronal third was absent in Model A, in contrast with Models B and C (Figures 5 and 6), where stress was concentrated at the first threads of the implants.

We observed a larger number of fringes in Model B compared with the other models, and the stress concentration was higher at the apical level. Models A and C had the same number of fringes. However, the fringes were more broadly distributed in Model C (Figure 6), indicating a lower stress concentration compared with Model A. The number of photoelastic fringes revealed stress magnitudes of Model B > Model A > Model C.

**Oblique load**

Analysis of the models subjected to oblique loads (Figures 7, 8, and 9) revealed that the stress concentration patterns were similar for all 3 models. Stress was observed in the cervical and middle thirds (distal region) and in the apical portion of the implants. The highest stress concentrations were located at
the apex of the implant on the contralateral side of load application in all 3 models.

In Models A and B (Figures 7 and 8), the photoelastic fringes were in close proximity, corresponding to higher stress concentration, and were located at the apex of the implant in the mesial region. In Model C (Figure 9), the stress concentration was lower. Model B exhibited the greatest number of fringes, and the number of fringes was similar between Models A and C. The order of stress magnitude in the models was Model B > Model A > Model C.

The pattern of the fringes when models were under oblique load application was different from that under axial loads. In oblique loads, the number of fringes increased, and they were in much closer proximity, corresponding to higher stress concentration.

**DISCUSSION**

Analysis when the axial load was applied showed that Model A (platform switching) presented a stress distribution pattern that differed from that of the other models, with more centralization of stresses at the implant apex. This result can be explained by the load concentration at the IAJ,\(^{14}\) which purportedly transfers the stress to a more centralized position.\(^{12,2}\) This theory of centralization was verified by Maeda et al\(^{17}\) through finite element analysis, which revealed that stress concentrations on a platform switching implant are located at the center of the implant-abutment joint (at the level of the implant screw).

Consistent with previous studies,\(^{2,4,9,10,12}\) the stress concentrations in Model A decreased at the cervical region. This altered the horizontal position of the microgap in the IAJ, resulting in a reduced horizontal component of bone loss after abutment connection. From a biological standpoint, this change decreases bone loss in the cervical area. Similar findings have been observed in histological, histomorphometric,\(^{1,13}\) clinical,\(^{2,4,9,10}\) and retrospective studies.\(^{14,16,21}\) Finite element analyses\(^{17,18}\) have also verified that the stress concentration is lower or absent at the cervical region of platform switching implants compared with standard implants.

Compared with Model C, where the stress magnitude was lower and more dissipated, Model B displayed higher stress concentrations. This difference in stress concentration was due to the increased surface of the wide-diameter implants. Ding et al\(^{21}\) found that use of wider implants increases the area of the bone-implant contact surface, allowing engagement of a maximal amount of bone and theoretical improvement of stress distribution in the surrounding bone. Several additional studies using various methods to compare regular and wide-diameter implants found better biomechanical behavior among the wide-diameter implants.\(^{21–23}\)

All models showed higher magnitudes and stress concentrations when an oblique load was applied. An oblique force is less

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Single implant 5.00 mm in diameter, with Platform 5.00 mm/4.1 mm abutment (platform switching)</td>
</tr>
<tr>
<td>B</td>
<td>Single implant 3.75 mm in diameter, with Platform 4.1 mm/4.1 mm abutment (conventional/regular diameter)</td>
</tr>
<tr>
<td>C</td>
<td>Single implant 5.00 mm in diameter, with Platform 5.00 mm/5.00 mm abutment (conventional/wide diameter)</td>
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favorable than an axial load for stress distribution along the implant. Mathematical analyses have shown that oblique force application on the crown surface produces lateral force components, creating moments on the implant and thus producing higher stress concentrations.

Comparison of Models A and C revealed decreasing stress concentrations at the cervical and middle thirds of Model A. This observation also was noted by Liu et al in a study using 3-dimensional finite element analysis to compare the platform switching technique vs a standard protocol. Investigators found that the platform switching design improved stress distribution and decreased maximum stresses in peri-implant bone around the implant cervix.

The platform switching technique is a simple and viable technique that does not increase implant treatment costs. This technique is an effective way to control circumferential bone loss around dental implants, although it has been tested by few biomechanical studies. The present study verified the favorable biomechanical behavior of the platform switching technique and found no significant differences between wide-diameter and platform switching implants with respect to the magnitude of stress.

**CONCLUSIONS**

1. Stress concentrations decreased in the cervical region of the platform switching implant.
2. Models A (platform switching) and C (conventional/wide-diameter) displayed similar stress magnitudes.
3. Model B (conventional/regular diameter) displayed the highest magnitude and stress concentration.

**ABBREVIATIONS**

IAJ: implant-abutment junction
ICT: inflammatory cell infiltrate

**REFERENCES**


