10.5005/jp-journals-10024-1021
ORIGINAL RESEARCH

Photoelastic Comparison of Single Tooth Implant-Abutment-Bone of Platform Switching *vs* Conventional Implant Designs

Fabiana Rossi, Adriana Cristina Zavanelli, Ricardo Alexandre Zavanelli

ABSTRACT

Objectives: The maintenance and stability of peri-implantar soft tissue seem to be related to the crestal bone around the implant platform and different implant designs connections might affect this phenomenon. The aim of this study was to evaluate by photoelastic analysis the stress distribution in the cervical and apical site of implant-abutment interface of conventional implant joints (external hex, internal hex and cone morse) and compare to the novel platform switching design.

Materials and methods: It was fabricated photoelastic models using five different implant-abutment connection, one set of external hex (Alvim Ti, Neodent, Curitiba, Brazil), one set of internal hex (Full Osseotite, Biomet 3i, Florida, USA), one cone morse set (Alvim CM, Neodent, Curitiba, Brazil), and two sets of internal hex plus platform switching concept (Alvim II Plus, Neodent, Curitiba, Brazil) (Certain Prevail, Biomet 3i, Florida, USA). These models were submitted to two compressive loads, axial from 20 kgf (load I) and another (load II), inclined 45° from 10 kgf. During the qualitative analysis, digital pictures were taken from a polariscope, for each load situation. For the quantitative analyses in both situations of load, the medium, minimum and maximum in MPa values of shear strain were determined in the cervical and apical site. The Kruskal-Wallis test was used to compare the results between the different systems and between cervical and apical site were compared using Mann-Whitney U test.

Results: The results from qualitative analysis showed less concentration of strain in the cervical area to the internal hex plus platform switching (Certain Prevail), in both situation of load. The same results were get in the quantitative analysis, showing less stress concentrations around the implant Certain Prevail with internal hex plus the novel design (17.9 MPa to load I and 29.5 MPa to load II), however, without statistical significant difference between the systems.

Conclusion: The minor stress concentration strongly suggest the use of platform switching design as a manner to prevent bone loss around the implant-abutment platform.

Clinical Significance: From the result of this study its possible to make clinical decision for implant system which provides implant components with platform switching characteristics.

Keywords: Dental implants, Photoelasticity, Implant-abutments, Platform switching.

How to cite this article: Rossi F, Zavanelli AC, Zavanelli RA. Photoelastic Comparison of Single Tooth Implant-abutment-Bone of Platform Switching *vs* Conventional Implant Designs. J Contemp Dent Pract 2011;12(2):124-130.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

Implant therapy has become an increasingly common form of predictable oral rehabilitation with high reported success rates for implants placed in partially and complete edentulous arches for replacement of both single and multiple teeth.[1,2] Despite the high successful rates,[3] one commonly reported esthetic problem still remain and is related to the hard (crestal bone) and soft tissue maintenance (papilla), furthermore, bone resorption close to the first thread of osseointegrated implants is frequently observed during initial loading.[4]

For many years, the crestal bone level around dental implants has been considered when evaluating implant success to satisfy the criteria previously proposed, which states that a dental implant must have less than 2 mm of vertical bone loss apical to the implant-abutment junction (IAJ) during the first year of function and less than 0.2 mm annually after the first year.[5,6]

The bone loss that occurs so commonly is probably a result of inflammation of the soft tissue caused by bacteria penetrating the IAJ.[7] Recently, the reduction of crestal bone loss around an implant was described in a recent radiologic-clinical follow-up study in which implants with prosthetic connections of smaller diameter than the implant platform were used.[8-11] This phenomenon became a new implant concept known as platform switching, seems to reduce bone loss caused by the microgap, and may be correlated with a more internal localization of the IAJ with respect to the external rim of the implant platform.[8]

The biologic process responsible for this occurrence seem to be linked to distancing of the inflammatory connective tissue infiltrate from the alveolar crest, and this in turn results from a more inward displacement of the microgap on the implant platform.[4] Moreover, the clinical implications of platform switching are numerous, and all indicate greater long-term predictability in implant-prosthetic therapy by enabling preservation of the implant hard and soft tissue over time, especially in single-tooth esthetic clinical situations.[4]

Several implant-abutment interface designs are supposedly able to support the single-tooth restorations and this joint may be classified as external or internal connection and incorporate features for rotational resistance, indexing, and lateral stabilization, described as hexagonal, octagonal, cone screw, cone hex, cylinder hex, spline, cam, cam tube, and pin/slot.[12]

The external hexagonal interface was originally intended to provide a method to engaging the implant during surgical placement and in single-tooth restorations has also been used to supply an antirotational mechanism, resulting in the exposure of the implant-abutment interface and abutment screw to greater external loads and bending moments, which can lead to screw joint opening and screw loosening.[13,14]

The tapered cone-screw internal connection was first introduced in the morse taper system,[15,16] and the mating angle between the implant and the abutment taper was 8 degrees, which loosening torque required is 124% greater than the tightening torque of 25 N/cm.[17] The internal hexagonal junction improved internal stability of connection, the resistance to lateral loadings and distribution of stresses when compared with external hexagonal.[12]

Considering this scenario of novel internal connections designs of the implant-abutment, there is a need of biomechanical point of view to validate the data for clinical use, and the main reports considering this issue include only clinical or radiological follow-up, bone remodeling, histological or histomorphometric analysis.[18-22] Previous report[23] showed promising results in a biomechanical comparison with the novel design of platform switching, however, the study used a healing abutment instead a conventional implant-abutment system.

One of the experimental available techniques that can predict the mechanical response of a structure under an applied load is the photoelasticity, and this technique is based on the properties of transparent material that shows patterns of color with the stress distribution when viewed with polarized light.[24,25]

Considering the scarcity of data in the literature considering the novel concept of platform switching, the aim of this study was to analyze qualitatively and quantitatively the stress distribution in the cervical and apical site of the implant-abutment with conventional connections (external hex - EH, internal hex - IH, cone morse-CM) and compare with the novel platform switching design (PS), using the method of photoelasticity reflection and two different load conditions.

MATERIALS AND METHODS

The photoelastic model analysis used in this study involved five different implant-abutment of two commercial brands (Biomet 3i, Florida, USA and Neodent, Curitiba, Brazil), five different sets of implant-abutment connections (one set of external hex, one set of internal hex, two sets of internal hex plus platform switching and one set of cone morse joint) as described in Table 1, two loads (compressive axial load and 45° of inclined load) and two types of analysis (qualitative and quantitative).

For each set of implant-abutment, it was fabricated a photoelastic model from prototypes in polymethacrylate acrylic resin (PMMA, Orthodontic Resin, Dentsply, Milford, DE), resulting in five models for the study (Fig. 1). To assemble each model it was used 15 ml of Araldite resin GY 279 (GY 279 Araldite, Huntsman, Everbeg, Belgium) for 7 ml of hardener Aradur (Aradur, Huntsman, Everbeg, Belgium) following the manufacturer's recommendations.

Each photoelastic model was subjected to the application of two ways of compressive load, one axial (load I – 20 kgf) and one inclined at 45°(load II – 10 kgf) accordingly to the long axis of the implant-abutment. During the load

Table 1: The different implant brand, dimensions and type of the implants, the implant-abutment connections and type of abutment used in the study

Implant brand	*Implant model dimensions*	*Prosthetic connection*	*Abutment*
Neodent*	Alvim Ti (4.3 × 13 mm)	External Hex (EH)	Universal post
Neodent*	Alvim II Plus (4.3 × 13 mm)	Internal Hex Platform Switching (IH – PS)	Universal post
Neodent*	Alvim CM (4.3 × 13 mm)	Cone Morse (CM)	Universal post
Biomet 3i**	Full Osseotite (4 × 13 mm)	Internal Hex (IH)	Gengihue post
Biomet 3i**	Certain Prevail (4 × 13 mm)	Internal Hex Platform Switching (IH – PS)	Gengihue post

*Neodent, Curitiba, Parana, Brazil; **Biomet 3i, Palm Beach Gardens, Florida, USA

Fig. 1: Photoelastic model and points of interest analyzed at cervical and apical region

application, there were a qualitative and quantitative analysis of the strains generated in each set, which were then analyzed and compared.[26]

The models were positioned in the equipment for the load application developed in the Mechanical Laboratory at Sao Paulo University—Ribeirao Preto Dental School, and this equipment was coupled to a polariscope (PS-100 SF Polarimeter, Strain-optic Technologies, North Wales—PA, USA), composed of a load cell of 50 kgf (Kratos, Load Cell, Sao Paulo, Brazil) and a reader load display (IKE-01, Kratos, Sao Paulo, Brazil).

To the photoelastic qualitative analysis, the images were taken with the aid of a digital camera attached to polariscope (CCD Color Video Camera, GKB, Taiwan) and connected to a computer with specific software (Win-TV 4.8, Hauppauge Computer Works, USA).

The optical effects observed by polariscope were viewed by fringes that appear as colored bands called isocromatics, and these fringes indicate the regions that were subjected to strains, also each fringe shows a specific color that corresponds to the number of order fringe represented by "N".[26]

The images were recorded from each implant-abutment during the application of axial and inclined loads and qualitative analysis was based on the distribution patterns of isocromatics fringes under the different conditions of application of load. In this analysis, the photoelastic resin simulated the peri-implant bone and a colored fringe indicates how the applied load was distributed for each implant-abutment. The pattern of distribution of the fringes was compared between each set. Thus, in this analysis, when greater the proximity and number of fringes, greater was the stress concentration. When the greater was the number of fringe order (N), or the number of fringes, greater was the magnitude of stress.[25,26]

For quantitative analysis, the shear strain was determined in nine points of interest (POI) around each implant-abutment defined in a profile projector (Nikon 6C). Out of these points, six were in the cervical region around the implants and three in the apical region in accordance to Figure 1.[26]

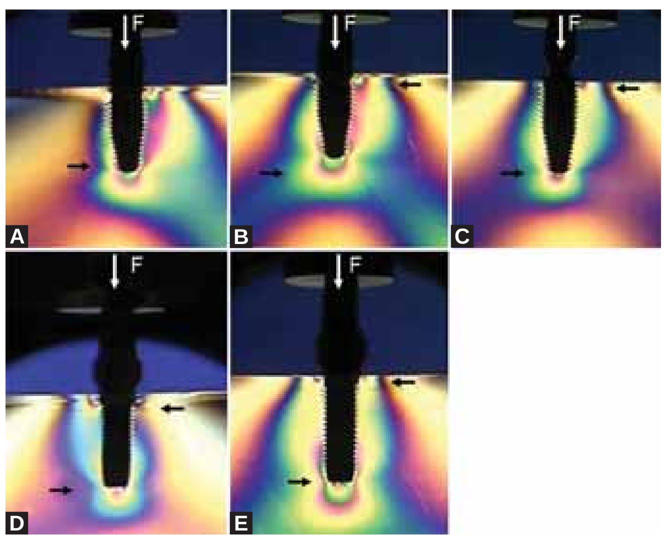
After calculating the shear strain at each POI analyzed, the values were placed on specific tables considering the load I and II of each implant-abutment set. With these data, it was calculated the mean and standard deviation of shear strain of each implant. The Kruskal-Wallis test was used for comparison of data and for comparison of data in each region (cervical and apical), it was used U of Mann-Whitney test.

RESULTS

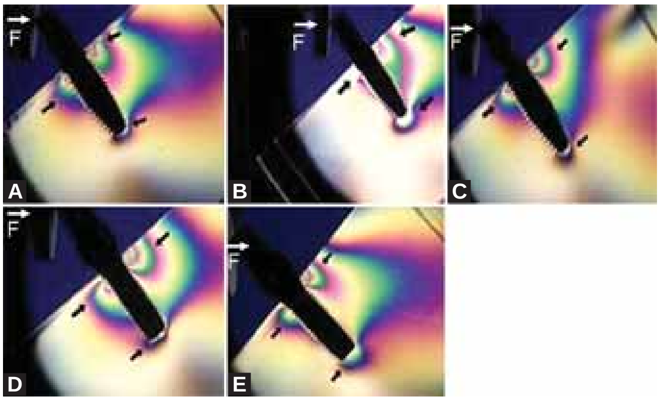
Qualitative Analysis with Axial Load (Load I)

Using the polariscope in circular mode and applying an axial load of 20 kgf (load I, marked "F" in Figures 2A to E) in each implant-abutment, the images of the isocromatic fringes were obtained according to Figures 2A to E. These fringes show the distribution of stress around the implant-abutment examined.

Looking at the implant platform, there was similarity in the concentration (proximity between the fringes) and magnitude of stress (order and number of fringes) around the implants of IH and CM, and slightly lower for the certain prevail implant with formation of violet and blue fringe order (N = 1). In cervical implants Alvim II Plus and Alvim CM, there were a formation of fringe 2 (N = 2). The highest stress concentration and magnitude were observed around the implant Alvim Ti (EH), with formation of red and green fringe (N = 3). Whereas the apical region, the lowest concentration and magnitude of stresses were observed around the Full Osseotite and Alvim CM (N = 1). The apex of implants Alvim Ti and Alvim II Plus there was formation of fringe 2 (N = 2). The greatest concentration of stress in the apical region was found around the Certain Prevail implant, with red and green fringe (N = 3).



Figs 2A to E: (A) Implant-abutment of EH with load I (Alvim Ti), (B) implant-abutment of IH-PS with load I (Alvim II Plus), (C) implant-abutment of MC with load I (Alvim CM), (D) implant-abutment of IH with load I (Full Osseotite), (E) implant-abutment of IH-PS with load I (Certain Prevail)



Figs 3A to E: (A) Implant-abutment of EH with load II (Alvim Ti), (B) implant-abutment of IH-PS with load II (Alvim II Plus), (C) implant-abutment of MC with load II (Alvim CM), (D) implant-abutment of IH with load II (Full Osseotite), (E) implant-abutment of IH-PS with load II (Certain Prevail)

Qualitative Analysis with Inclined Load at 45° (Load II)

With the application of load II (marked as “F” in Figures 3A to E), the patterns of fringes can be seen in Figures 3A to E.

Considering the cervical site, in the same side of load application, there was no significant formation of stress around the implant Alvim II Plus, there was formation of fringe 1 (N = 1) around the Certain Prevail implant. Already around the implants Alvim CM, Alvim Ti and Full Osseotite, concentration and magnitude of stress were similar (N = 2) and higher than the previous implants. In the cervical region against the application of lateral load was observed similar magnitude of strain around the implants Alvim II Plus, Alvim CM and Certain Prevail, with a fringe order of 3 (N = 3) with lower concentration of stress around the Certain Prevail implant. Around the implants Alvim Ti and Full Osseotite, the concentration of stress was higher, with formation of a fringe 4 (N = 4).

In the apical site, the concentration and magnitude of stress were similar, but slightly larger around the implants Alvim II Plus and Certain Prevail (N=1). Considering the pattern of distribution of strains, the qualitative analysis in both conditions of loading, showed better results to implants with IH and PS, by concentrating less stress in the platform, which is critical to maintaining the esthetics. It was also possible to see the worst performance of all implants with EH, which has focused more stress in this spot.

Quantitative Analysis with Axial Load (Load I)

Considering the points in the cervical region with the application of the load I, the values of shear strain were obtained according to Table 2.

The implant Certain Prevail (IH-PS) showed the lowest values of shear strain in the implant platform, however without statistically significant difference in comparison with other implant-abutment sets. The Alvim Ti implant showed numerically higher values of strain, however, without statistically significant difference in relation to the other sets.

The values of shear strain of the apical site can be reached in Table 3. There was no statistically significant difference between the assemblies, and the lowest concentration of strain was observed at the apex of the implant Full Osseotite.

Quantitative Analysis with Inclined Load at 45° (Load II)

Considering the cervical area, the values of shear strain can be reached in Table 4, and the results of this analysis showed no statistically significant difference between the assemblies. Even without statistical difference ($p < 0.05$), lower shear strain was observed, again, in the cervical of the Certain Prevail implant (29.5 MPa). At the other extreme, the highest average of stress magnitude was observed around the Full Osseotite implant (49.3 MPa).

The values of shear strain in the apical area can be reached in Table 5. It was observed that the lower shear strain was found around the apex of the Full Osseotite implant, with an average value of 20.7 MPa and this result was statistically significant ($p < 0.05$) different from the other implants-abutment set.

DISCUSSION

The tissue changes that occur around the implants involve loss of bone and gingival support, which can compromise the esthetic aspect. Several factors have been suggested as causal or aggravating these changes, such as design of implants, type of connection between implant-abutment, the presence of microorganisms, concentration of stress, trauma caused by the exchange of prosthetic components, among others.[9]

Recently, it was observed that some combinations of implant-abutments that incorporate the concept of platform switching create minor tissue changes, as compared to conventional assemblies,[8,9,11] although it is unclear which features bring this new concept that make it more predictable.

Considering these factors and assuming that strains generate biological responses in bone tissue surrounding the implants,[3,4,24] this study proposed to evaluate the stress generated around these new implant-abutments who seem to bring better esthetic responses, but little is known about the biomechanical characteristics of them. One reported data using finite element analysis,[23] states that the stress level in the cervical bone area at the implant was greatly reduced when the narrow diameter implant was connected compared with the regular-sized one.

Table 2: Media, minimum, maximum values (MPa) and standard deviation of the shear strain, according to each implant-abutment set in the cervical spot, considering the load I*

Implant model	*Prosthetic connection*	*Medium*	*Minimum*	*Maximum*	*Standard deviation*
Alvim Ti	EH	35.8	24.2	51.1	10.5
Alvim II Plus	IH-PS	29.8	18.1	42.7	10.6
Alvim CM	CM	32.4	23.5	38.6	5.4
Full Osseotite	IH	30.6	21.1	52.7	11.4
Certain Prevail	IH-PS	17.9	0,0	40.9	19.8

*p = 0.591 (Kruskal-Wallis test)

Table 3: Media, minimum, maximum values (MPa) and standard deviation of the shear strain, according to each implant-abutment set in the apical spot, considering the load I*

Implant model	*Prosthetic connection*	*Medium*	*Minimum*	*Maximum*	*Standard deviation*
Alvim Ti	EH	67.3	35.6	87.1	27.7
Alvim II Plus	IH-PS	56.0	36.5	67.8	17.0
Alvim CM	CM	64.2	55.2	77.1	11.5
Full Osseotite	IH	35.6	35.6	35.6	0.0
Certain Prevail	IH-PS	52.8	35.6	62.1	14.9

*p = 0.217 (Kruskal-Wallis test)

Table 4: Media, minimum, maximum values (MPa) and standard deviation of the shear strain, according to each implant-abutment set in the cervical spot, considering the load II*

Implant model	*Prosthetic connection*	*Medium*	*Minimum*	*Maximum*	*Standard deviation*
Alvim Ti	EH	37.9	0.0	79.6	41.6
Alvim II Plus	IH-PS	37.9	0.0	95.8	43.0
Alvim CM	CM	32.1	0.0	73.5	35.5
Full Osseotite	IH	49.3	34.9	71.2	16.3
Certain Prevail	IH-PS	29.5	0.0	66.7	28.4

*p = 0.895 (Kruskal-Wallis test)

Table 5: Media, minimum, maximum values (MPa) and standard deviation of the shear strain, according to each implant-abutment set in the apical spot, considering the load II*

Implant model	*Prosthetic connection*	*Medium*	*Minimum*	*Maximum*	*Standard deviation*
Alvim Ti	EH	39.1	32.7	48.9	8.6
Alvim II Plus	IH-PS	33.3	24.9	43.9	9.7
Alvim CM	CM	21.4	19.7	24.5	2.7
Full Osseotite	IH	20.7	17.8	26.5	5.0
Certain Prevail	IH-PS	23.2	18.3	28.5	5.1

*p = 0.049 (Kruskal-Wallis test)

Despite the limitations, the method chosen for this study was the photoelastic analysis of strains, allowing the direct visualization of the regions of greatest stress has cost more accessible for other methods and allow the use of real structures.[24-26]

Considering the qualitative analysis of the situation of load I, the results of this study showed lower concentration of tensions in the region around the cervical range of implant-abutment with IH and PS (Certain Prevail), which is in accordance to previous report,[23] and despite the different methods of analysis. The hypothesis in this study to explain this lower concentration was a change in the distribution of strain, it is more concentrated in the center of the implant with PS.

On the other hand, the highest concentration and magnitude of stress were observed in the cervical spot of implant-abutment with EH (Alvim Ti). It is well documented in the literature that the external hexagonal joints are less stable and concentrated more stress as compared to the internal joints, especially in single clinical situations as evaluated in this study.[12,17] The worst distribution of stress has been associated with increased bone resorption that occurs around the implant platform.[18-22]

In the apical region with load I, the Certain Prevail implant showed higher concentration of stress when compared to the EH connection, showing a wider pattern of distribution in this region, and this same pattern of stress distribution was observed in a previous report.[23,26] According to these authors, the different distribution of strain between implants with EH and IH can be explained by the higher surface of the connection joints of IH, so that the largest side of the abutment directs the forces in the long axis of the implant, decreasing the tension in the neck and increasing them at the apex.

Considering the load II, the qualitative analysis showed a similar distribution of tension in the cervical region between the implants of IH with PS and CM, with a fringe of 3 (N = 3), and slightly lower for the implant Certain Prevail. Again, the implant-abutment with EH showed higher concentrations of tension in the neck, with a fringe of 4 (N = 4). This result also agrees with the investigations of Bernardes et al (2006) that found lower concentration of stress in the neck of implants with IH, not subjected to axial loads, suggesting that the internal connections seems to distribute the stress better than external hexagonal junctions. In the apical region, implants of IH with and without PS had greater concentration of stress, again showing a wider pattern of distribution in this region.[23,26]

As can be seen in qualitative analysis, the Certain Prevail implant focused less strain in the neck, when compared to other implants. It might be that the biomechanical advantage of this implant design is the result of his collar,[10] which is wider than the other implants of IH. It has 4.8 mm diameter, while the others have 4.1 mm (Full Osseotite) and 4.3 mm (Alvim II Plus). This could explain the lower performance of the implant Full Osseotite which has the same dimensions and connection of Certain Prevail implant, differing only in the smallest of the collar.

Considering the selected points to perform the quantitative analysis, with load I, there was no statistically significant difference between the assemblies, both in the cervical region and in the apical region. Previous report also found no difference in the distribution and concentration of stress between implants with external and internal hexagonal junctions, when subjected to axial loads.[23,24,26]

In the situation of load II, in the neck, lower shear strain was observed again in the neck of implant with IH and PS (Certain Prevail—29.5 MPa). There was no statistically significant difference in the magnitude of shear strain between the groups ($p = 0.895$). This result differs from those obtained in studies by Bernardes et al 2006 and Maeda et al 2007, who found differences in the distribution and magnitude of strain between implants with EH and IH, when not subjected to axial loads. In both studies cited, the implants with IH had lower concentration of strain in the cervical region.

Considering the apical region, the less stress magnitude was found around the apex of the implant Full Osseotite (20.7 MPa on average), being statistically significant between all groups ($p = 0.049$). This result precludes the study of Maeda et al 2007, that obtained greater concentration of stress at the apex of implants of IH.

According to Mahler and Peyton (1955)[25] the results could be underestimated increasing the load and when using the photoelasticity to measure stress. Assuncao et al (2009), also warned to the low precision values when trying to quantify the stress using photoelasticity. Thus, these factors must be considered when analyzing the results of this study. It may be that no difference between the assemblies has been influenced by the little sensitivity in increasing load of quantitative analysis.

There is no consensus in the literature regarding the role of occlusal loading on peri-implantar bone resorption,[27] and is not yet completely clear how the use of the platform switching gets the best esthetic results. Care must be taken in extrapolating the results, as this study has limitations. The photoelastic resin is homogeneous and isotropic and therefore does not simulate the actual conditions of the bone. Similarly, the bone-implant interface in this study is considered homogeneous and continuous surface around the implant, which is not necessarily a reality. The shape and support the model were not similar to the conditions of the real structure. The application of static loads also not consistent with the complexity of the masticatory cycle. Another limiting factor of the study was the direct application of the load in the abutments, without the preparation and cementation of prosthetic crowns, which could somehow dissipate the forces.

Although it is still a controversial issue and taking into account the limitations of this study, for the load I and II, the results of qualitative analysis indicated lower concentration and magnitude of stress in the neck on implants of IH with PS, suggesting the clinical use of this new concept by focusing less stress than the other implants.

The results of this study strongly suggest that future research might include measurements on different methodologies and using several different sets of implants, with their respective connections and abutments, plus the addition of longitudinal studies.

CONCLUSIONS

According to the results and considering the limitations of this study, it was possible to conclude that:

1. In the qualitative analysis, the implant-abutment set with IH + PS showed the lower stress concentration and magnitude in the implant neck area, in both conditions of axial and inclined load.
2. In the quantitative analysis, there were no statistically significant differences between the assemblies, considering the magnitude of shear strain in selected points of the neck in both conditions of load, however in the apical spot with load II, the implant-abutment set of IH showed the lowest value of shear strain.

REFERENCES

1. Levin L. Dealing with dental implant failures. J Appl Oral Sci 2008;16(3):171-75.
2. Pye AD, et al. A review of dental implants and infection. J Hosp Infect 2009;72(2):104-10.
3. Astrand P, et al. Implant treatment of patients with edentulous jaws: A 20-year follow-up. Clin Implant Dent Relat Res 2008; 10(4):207-17.
4. Luongo R, et al. Hard and soft tissue responses to the platform-switching technique. Int J Periodontics Restorative Dent 2008; 28(6):551-57.
5. Albrektsson T, et al. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1(1):11-25.
6. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989;62(5):567-72.
7. Quirynen M, van Steenberghe D. Bacterial colonization of the internal part of two-stage implants. An in vivo study. Clin Oral Implants Res 1993;4(3):158-61.
8. Gardner DM. Platform switching as a means to achieving implant esthetics. NY State Dent J 2005;71(3):34-37.
9. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int J Periodontics Restorative Dent 2006;26(1):9-17.
10. Vela-Nebot X, et al. Benefits of an implant platform modification technique to reduce crestal bone resorption. Implant Dent 2006; 15(3):313-20.
11. Baumgarten H, et al. A new implant design for crestal bone preservation: Initial observations and case report. Pract Proced Aesthet Dent 2005;17(10):735-40.
12. Binon PP. Implants and components: Entering the new millennium. Int J Oral Maxillofac Implants 2000;15(1):76-94.
13. Jorneus L, Jemt T, Carlsson L. Loads and designs of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7(3):353-59.
14. Rangert B, Jemt T, Jorneus L. Forces and moments on Branemark implants. Int J Oral Maxillofac Implants 1989;4(3): 241-47.
15. Ledermann PD, Schroeder A, Stich H. The ITI hollow-cylinder implant (I). Construction materials coating instrumentation. Quintessenz 1981;32(8):1377-85.
16. Schroeder A, et al. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed surfaces. J Maxillofac Surg 1981;9(1):15-25.
17. Gokcen-Rohlig B, et al. Survival and success of ITI implants and prostheses: Retrospective study of cases with 5-year follow-up. Eur J Dent 2009;3(1):42-49.
18. Calvo-Guirado JL, et al. Immediate maxillary restoration of single-tooth implants using platform switching for crestal bone preservation: A 12-month study. Int J Oral Maxillofac Implants 2009;24(2):275-81.
19. Canullo L, Rasperini G. Preservation of peri-implant soft and hard tissues using platform switching of implants placed in immediate extraction sockets: A proof-of-concept study with 12 to 36 month follow-up. Int J Oral Maxillofac Implants 2007; 22(6):995-1000.
20. de Oliveira RR, et al. Bone remodeling adjacent to Morse cone-connection implants with platform switch: A fluorescence study in the dog mandible. Int J Oral Maxillofac Implants 2009;24(2): 257-66.
21. Degidi M, et al. Immediately loaded titanium implant with a tissue-stabilizing/maintaining design (‘beyond platform switch’) retrieved from man after 4 weeks: A histological and histomorphometrical evaluation. A case report. Clin Oral Implants Res 2008;19(3):276-82.
22. Prosper L, et al. A randomized prospective multicenter trial evaluating the platform-switching technique for the prevention of postrestorative crestal bone loss. Int J Oral Maxillofac Implants 2009;24(2):299-308.
23. Maeda Y, et al. Biomechanical analysis on platform switching: Is there any biomechanical rationale? Clin Oral Implants Res 2007;18(5):581-84.
24. Assuncao WG, et al. Biomechanics studies in dentistry: Bioengineering applied in oral implantology. J Craniofac Surg 2009.
25. Mahler DB, Peyton FA. Photoelasticity as a research technique for analyzing stresses in dental structures. J Dent Res 1955; 34(6):831-38.
26. Bernardes SR, et al. Análise fotoelástica da união de pilar a implantes de hexágono externo e interno. Implant News 2006; 3(4):355-59.
27. Carlsson GE. Dental occlusion: Modern concepts and their application in implant prosthodontics. Odontology 2009;97(1): 8-17.

ABOUT THE AUTHORS

Fabiana Rossi

Postgraduate Student, Department of Prevention and Oral Rehabilitation, FO-UFG, Goiás, Brazil

Adriana Cristina Zavanelli

Assistant Professor, Department of Dental Materials and Prosthodontics, FOA-UNESP, São Paulo, Brazil

Ricardo Alexandre Zavanelli
(Corresponding Author)

Associate Professor, Department of Prevention and Oral Rehabilitation, Avenida Dep. Jamel Cecilio, 2496, Jardim Goiás 74810-100, Goiânia-Goiás, Brazil, Phone: +5562-30883820, e-mail: ricardozavanelli@hotmail.com