Fracture Resistance of Implant Abutments Following Abutment Alterations by Milling the Margins: An In Vitro Study

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This in vitro study evaluated the effect of different levels of preparation of an implant abutment on its fracture resistance. The study evaluated abutments that incorporated a platform switch (Myriad Plus Abutments, Morse Taper Connection) and Standard abutments (BioHorizons Standard Abutment, BioHorizons Inc). Each abutment was connected to an appropriate implant and mounted in a self-cured resin base. Based on the abutment preparation depths, 3 groups were created for each abutment type: as manufactured, abutment prepared 1 mm apical to the original margin, and abutment prepared 1.5 mm to the original margin. All the abutments were prepared in a standardized manner to incorporate a 0.5 mm chamfer margin uniformly. All the abutments were torqued to 30 Ncm on their respective implants. They were then subjected to loading until failure in a universal testing machine. Abutments with no preparation showed the maximum resistance to fracture for both groups. As the preparation depth increased, the fracture resistance decreased. The fracture resistance of implant abutment junction decreases as the preparation depth increases.

Key Words: implant, abutment, milling, fracture resistance

INTRODUCTION

An increase in the predictability, success rates, and applications of implantology has resulted in a paradigm shift in the treatment of patients with missing teeth. Implant dentistry has contributed significantly to rehabilitation of partial and complete edentulism. The implant abutment junction is the most critical zone of the entire implant retained restoration, as it determines the strength and stability of the implant supported restoration and is most prone to failure.[1,2]

Implant abutment connections are primarily of two types: the external connections and the internal connections. The external connections were popularly characterized by the external hexagon connection, which facilitated easy removal and placement of the abutments. However, they did not provide an anti-rotational ability. Due to their limited height, these abutments showed micro movements under high occlusal loads.[3] To overcome the problems of the external connections, internal connections were introduced. The internal connections are known to be mechanically stable, self-locking, and reduce the stress on the crestal bone.[3] Different implant systems utilize various internal connections. Some points of difference among the various internal connection systems include (1) intimacy of approximation between the abutment's surface and the internal walls of the implant fixture, (2) depth of penetration of the abutment in the fixture, (3) presence of antirotational interlocking, (4) number and shape of antirotational or guiding grooves, and (5) abutment diameter at the platform level.[4] These different features cause some connections to be more rigid than others, and they demonstrate a higher fracture resistance.

Studies by Hermann et al have stated that crestal bone loss typically occurs about 2 mm apical to the implant abutment junction.[5,6] This eventually leads to gingival recession, which causes exposure of the abutments with subsequent implications.[7] This is more prominent in areas where the gingival biotype is thin. In esthetically critical areas, such as the maxillary anterior area, exposure of the abutment can cause serious esthetic problems for the patient and a major clinical challenge for the clinician. Altering the margins of the abutment by milling them can lead to reduction in strength of the abutment, which may eventually result in failure of the restoration.

The concept of platform switching uses smaller diameter abutments on a larger diameter implant body.[8] Due to reduced diameter of the platform switch abutments, their chances of failure are particularly high, especially in situations where they have been adjusted by grinding to accommodate esthetic

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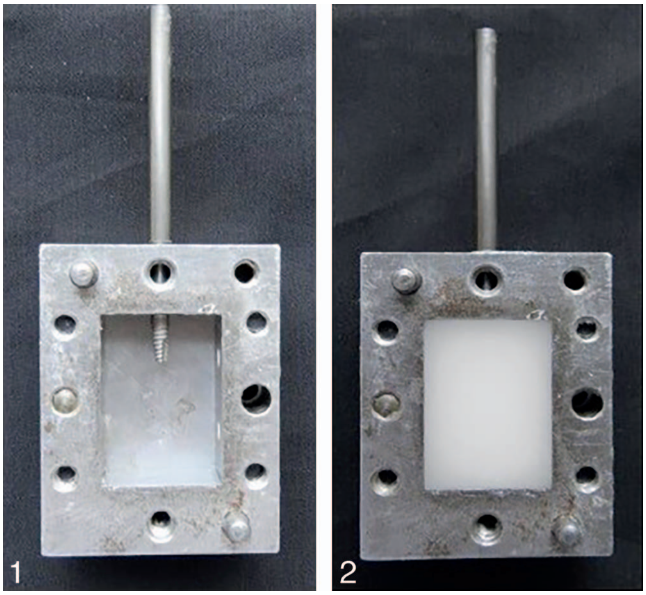

Figures 1 and 2. Figure 1. Implant held in place in the mold assembly. **Figure 2.** Self-cure acrylic resin poured into the mold cavity.

requirements and improving retention in cases with a prosthetic space. Att et al studied the fracture resistance of zirconia abutments in vitro. They showed that the fracture resistance decreased after modifications of the wall thicknesses of the abutments.[9] Similarly, DiPede et al reported that fracture resistance of solid abutments decreased after alterations of the abutments to various depths.[10] The effects of grinding/machining procedures on the fracture resistance of implant abutments have not been conclusively documented.

The literature does not conclusively report on the comparison of fracture resistance of standard abutments and abutments that incorporate a platform switch milled to different depths. The objective of this study was to compare the fracture resistance between a standard abutment (with an internal hexagon connection to the implant) and an abutment that incorporated a platform switch (with an internal conical or Morse taper connection to the implant) when the abutments were prepared to different apico-coronal depths.

Materials and Methodology

Materials

The study evaluated abutments which incorporated a platform switch (Myriad Plus Abutments, Equinox Medical Technology, Amersfoort, The Netherlands) and standard abutments (BioHorizons Standard Abutment, BioHorizons Inc). Standard abutments (BioHorizons Inc, Birmingham, Ala). had an internal hexagonal connection and served as a control group. The abutments that incorporated a platform switch (Myriad Plus Abutments, Equinox Medical Technology) had an internal conical connection and formed the test groups. Two different implant-abutment connections were thus evaluated.

The Myriad Plus implants (Equinox Medical Technology) were 11 mm length and 3.8 mm diameter, and Biohorizons Tapered Internal Implants (BioHorizons Inc) were 10.5 mm length and 3.8 mm diameter.

A stainless steel mold was constructed so that each implant could be oriented in the same angulation to maintain standardization (Pooja Fabricators, Pune, Maharashtra, India). Each implant was held in place by a custom made stainless steel rod in the mold assembly (Figure 1). A separating medium (silicone grease) was applied on all sides of the stainless steel components (Pooja Polymers, Pune). Self-cure acrylic resin (DPI-RR Cold Cure, Mumbai, Maharashtra, India) was mixed as per the manufacturer's recommendations and poured into the mold space to obtain blocks 30 mm $\times$ 20 mm $\times$ 15 mm (Figure 2).

Thirty such blocks (n = 10) were prepared by incorporating the Myriad Plus implants, and 10 such blocks were prepared by incorporating the BioHorizons implant into each block.

Methodology

The abutments were torqued to 30 Ncm on their respective implants. All abutments were prepared using a parallel milling device (AF 350, Amann Girbach North America, Charlotte, NC). A new bur was used for each preparation. All preparations were done by same operator to ensure standardization. Standard abutments (BioHorizons Inc) were used as the control group (Figure 3a). They were prepared with the incorporation of a chamfer margin of 0.5 mm cervical to the original margin of the abutment. Based on the abutment preparation depths, 3 groups (n = 10) were created for the Myriad Plus abutments, which incorporated the platform shift. The abutments were classified into three groups: as manufactured (Group 1; Figure 3b), prepared 1 mm apical to the original margin (Group 2; Figure 3c), and abutments prepared 1.5 mm apical to the original margin (Group 3; Figure 3d). All the abutments were prepared in a standardized manner to incorporate a 0.5 mm chamfer margin uniformly.

All the abutments were then subjected to loading in a universal testing machine at an angle of 45° and a crosshead speed of 1 mm/min until failure (Praj Metallurgical Laboratory, Pune, India; Figure 4). One-way ANOVA test was performed to compare the mean failure load of all the groups, and a Tukey post-hoc test was used to determine statistical significance among the means of the various groups.

Results

The mean fracture resistance of the abutments of the control group was 625.0 N. Group 1 showed a mean failure load of 632.2 N, Group 2 showed 587.25 N, whereas Group 3 showed 562.5 N (Figure 5). The one-way ANOVA test indicated that there was a highly significant difference among the mean values of all the groups ($P < 0.01$). The results of the Tukey post hoc test showed that there was a statistical significance between Groups 1 and 3; however, no statistical significance was seen between Groups 1 and 2 (Table). The mean values obtained thus indicated that the abutments with no prepara-

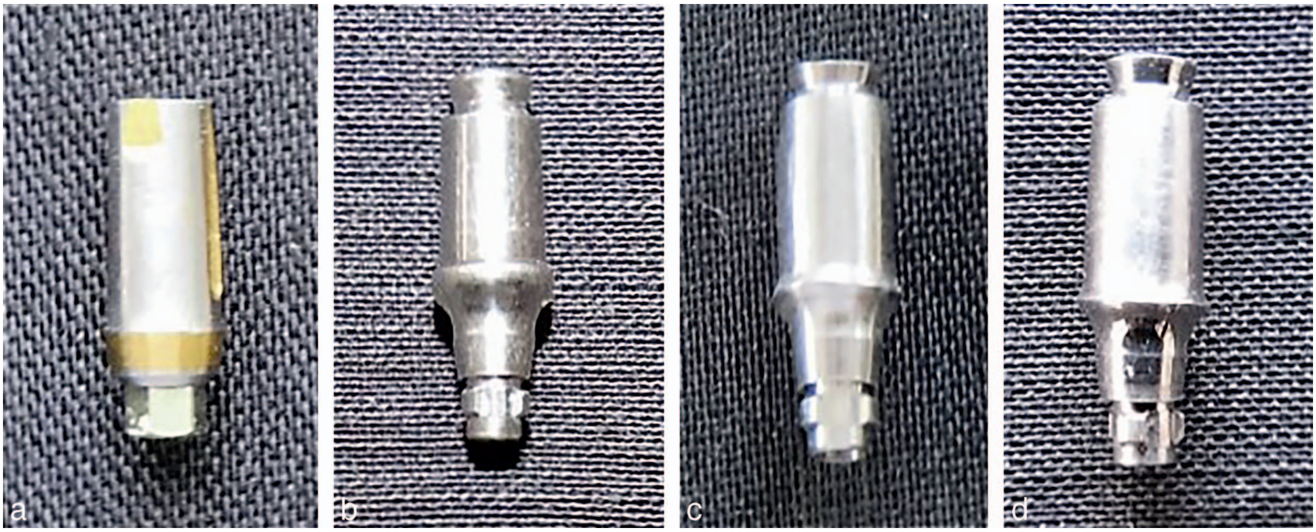

Figure 3. (a) Standard abutments (Control Group). (b) Myriad Plus abutments as supplied by the manufacturer (Group 1). (c) Myriad Plus abutments milled to a depth of 1 mm (Group 2). (d) Myriad Plus abutments milled to a depth of 1.5 mm (Group 3).

tion showed the maximum resistance to fracture for both groups. As the preparation depth increased, the fracture resistance decreased.

Discussion

Implant osseointegration is now a predictable phenomenon. The growth of implantology has led to the development of various commercially available implant systems. A weak link in an implant restoration is the implant abutment interface. It is in this region that a permucosal passage is created where initial tissue breakdown begins and results in eventual tissue necrosis and destruction around the implant.[11]

Implant abutments need to be modified to take restoration margins intrasulcularly or to increase crown retention. In modifying the abutments, the bulk of the abutment gets reduced, which potentially compromises the strength of the abutment and weakens them. This is particularly true in the case of platform switch abutments that have a narrower diameter. This in vitro study aimed to determine the acceptable length by which the platform switch abutments can be milled in an apical direction so that they can be used in clinical situations without compromising their strength.

The current study evaluated the mean fracture loads of standard and platform switched abutments before and after they were milled. The fracture resistance of the implant abutment junction decreased as the preparation depth increased (Figure 5). This current study was in agreement with studies by DiPede et al[10] and Alqahtani et al.[12] However, the first study used solid abutments that are not commonly used in

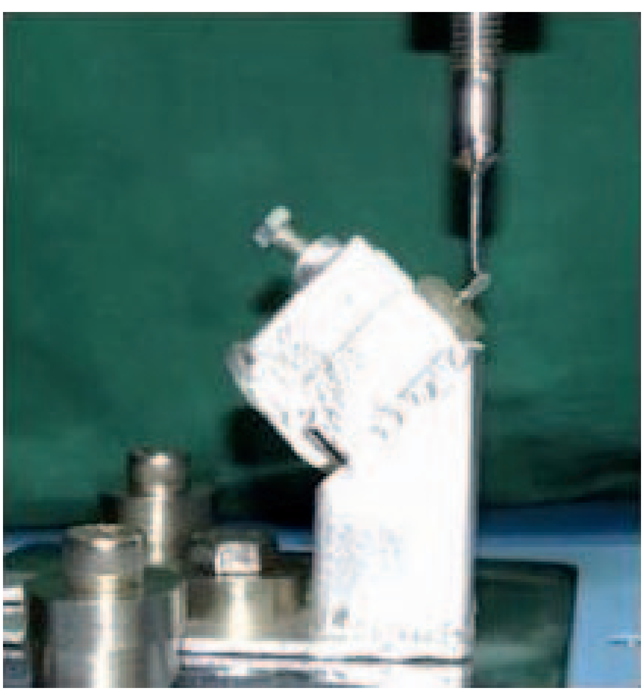

Figure 4. Testing of fracture resistance of the assembly.

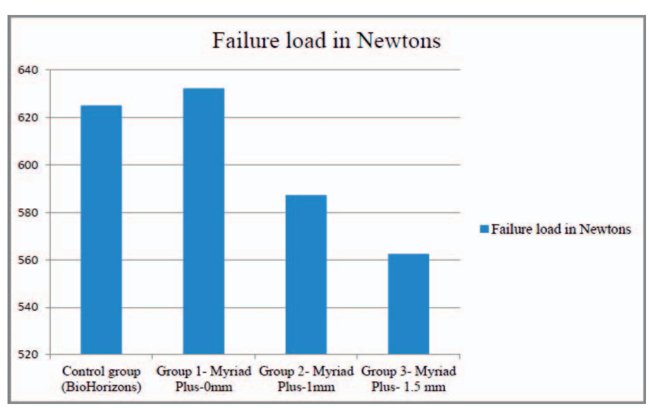

Figure 5. Mean failure loads of the various groups.

TABLE

Results of Tukey's post-hoc test

Treatments pair	Tukey HSD, Q statistic	Tukey HSD, p-value	Tukey HSD, inference
Group 1 (0mm) vs Group 2 (1 mm)	3.5603	0.0741662	insignificant
Group 1 (0mm) vs Group 3 (1.5 mm)	5.5206	0.0021678	$P < .01$
Group 1 (0mm) vs Control Group (BioHorizons)	0.5703	0.8999947	insignificant
Group 2 (1 mm) vs Group 3 (1.5 mm)	1.9603	0.5144634	insignificant
Group 2 (1 mm) vs Control Group (BioHorizons)	2.9900	0.1681008	insignificant
Group 3 (1.5 mm) vs Control Group (BioHorizons)	4.9503	0.0066003	$P < .01$

our country, and the latter used zirconia abutments that were assembled on implant analogues.

The results also showed that the fracture resistance was the highest in the platform-switched Myriad Plus abutments, which were not prepared or which were used as supplied by the manufacturer (Group 1). The milling of the abutment collar reduced their fracture resistance in Group 2 (abutments prepared 1 mm apical to the original margin) and Group 3 (abutments prepared 1.5 mm apical to the original margin). The decrease in fracture resistance on reduction up to 1 mm was not statistically significant (Table). As the depth increased, the fracture resistance decreased. Milling the abutment reduced the metal thickness and made it weaker compared to the abutments supplied by the manufacturer.

The fracture resistance of the BioHorizons abutments (control group) was less when compared to the Myriad Plus abutments. This could be attributed to the Morse taper configuration of the Myriad Plus abutments, where a tapered abutment is placed into the nonthreaded shaft of the implant with the same taper.[13,14]

Preparation of the abutments always reduced fracture resistance.[10,12] Our study showed that milling the abutments to 1 mm depth is acceptable. However, greater depth would probably reduce the metal thickness, incorporate surface flaws, and make them more prone to fracture. The mean fracture loads of the various groups also indicate that it is better to use the abutments as supplied by manufacturer.

Implant placement is critical with platform switch abutments to position the milled abutment margins adequately subgingival, establish an appropriate emergence profile, and yet provide adequate height for the retention of the crowns. The platform switched abutments with Morse taper connections have a high fracture resistance. Platform-switching has been known to limit crestal resorption, preserve peri-implant bone levels, and have higher primary stability at insertion.[15–17]

The limitations of this study were that full coverage crowns were not fabricated on the abutments. Fracture resistance was measured under static loading, which does not completely simulate conditions in vivo. Hence, the clinical implications of the failure load numbers may be difficult to obtain.

Further clinical studies are needed using different abutments and implant designs, abutments of different materials, and studying customized abutments using the above-described technique. It will also be interesting to investigate the effect of occlusal restorative materials along with the study design described.

CONCLUSIONS

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

- Platform switch abutments with a Morse taper connection show higher fracture resistance than does the standard conventional abutment.
- Margin preparation to a more apical level reduces the fracture resistance significantly and keeps the abutment at a higher risk to fracture.
- For the abutment configuration studied, 1 mm reduction towards the apical region of the platform-switched abutment seems permissible.

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