Evaluation Of Gingival Tissue Entrapment On Abutment Screw Loosening Of Titanium And Zirconium Abutments: An In Vitro Pilot Study

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Abstract- The study compared the difference in removal torque values of titanium/titanium implant abutment interface and titanium/zirconium implant abutment interface with and without entrapped soft tissue, employing an in vitro model. Porcine tissue specimens were prepared to thickness of 0.5 mm. Twenty internal hex implants were embedded in acrylic block. Four groups (n = 5) were studied. Titanium and zirconium abutments were tightened with and without entrapped tissue, to each of the 20 titanium implants. Using a digital torque gauge all the abutments were torqued to 20 Ncm (Newton-Centimetre). Specimens with entrapped tissue were immersed in 1 M NaOH (Molar sodium hydroxide) for 48 hours to dissolve tissue to simulate salivary breakdown in the oral cavity. Mean and standard deviation was calculated for each group. Mann Whitney U test was used to compare reverse torque values between two groups. Statistically significant variation in reverse torque values was found between all groups with and without tissue entrapment, ($p < 0.05$). The difference in torque drop for Zirconium/Titanium implant abutment interface with and without tissue entrapment was found to be (12.12 Ncm) and (13.48 Ncm) respectively after 48 hours. The difference in torque drop following 48 hours noted for Titanium/Titanium interface with and without tissue entrapment was found to be (13.86 Ncm) and (15.87 Ncm) respectively. Study revealed that tissue entrapment significantly lowers the reverse torque values.

Keywords: screw loosening, tissue entrapment, implant abutment interface, zirconium abutment, titanium abutment, internal hex implant

1. INTRODUCTION

Dental implants have been receiving wide acceptance as a highly successful rehabilitation method. They are becoming popular, due to patient acceptance and high survival rates [1].

Dental Implant technology has been continuously evolving over the years, providing patients with unmatchable levels of effectiveness, affordability and convenience. Implant dentistry progressed in the past century, focusing on materials, designs and techniques and by serving as quality anchorages for various conventional dental prosthesis. By twentieth century, numerous sophisticated techniques had been developed, comprising subperiosteal, transosteal and blade implants.

In two-piece implant systems, the implant and abutment are connected by means of a connecting screw. The connection between the two components are of different geometry and design like internal hex, external hex, Morse taper, tri-channel etc depending upon the manufacturer. According to Mc Glumphy et al. the screw joints consist of two components clamped together by a screw. Abutment and implant are also held together by a screw [2]. A specified torque is applied to tighten the screw. The force developed within the screw is called as preload. Fatigue life of abutment screw can be maximized by achieving optimal preload at implant/abutment connection. Attaining the specified preload also helps to prevent screw loosening [3]. Various authors pointed out that, loss of preload results in screw loosening [1].[4-6].

Screw loosening is a common prosthetic complication encountered while restoring with dental implants. This will make the prosthesis mobile, thereby creating a need to access the abutment screw for retrieval. Studies have demonstrated that insufficient preload or under tightened abutment screws depicted greater micro movement in the implant/abutment interface, that leads to loosening of screw, failure of joint and ultimately prosthetic failure. Abutment screw loosening lead to inflammation of gingiva, fracture of the abutment screw and failure of implant [4-6]. Benin et al. proposed that screw loosening depends on reduction of preload, settling and elongation of screw in an implant/abutment complex [7]. The applied torque or preload is achieved, based on variables such as the properties of materials in contact, presence of lubricants, settling of screw and the initial torque applied [8].

A clean implant/abutment interface is essential for accurate fit of abutment into the implant, especially during metal trial and final insertion. The same sequela results when tissue entrapment happens between implant/abutment joints. Tissue entrapment results in insufficient preload due to interference of soft tissue. It has been advocated that micro motion between implant components may cause peri-implant irritation, inflammation, gingival tenderness and gingival hyperplasia. Entrapped tissue undergoes ischemia and subsequent necrosis there by creating a space between the components. The resulting space created at the abutment/implant connection can lead to decrease in achieved torque values for the abutment screw. This leads to screw loosening [9,10].

There exist specific tissue retraction procedures, developed for fixed Partial Dentures to reduce the tissue interference during procedures. The methods used are gingival retraction cord, electrosurgery, injectable chemical retract ants and lasers, and they are used along with natural tooth abutments [11]. The use of standard and custom healing abutments and the wide emergence profile, are all the methods used to attain gingival tissue retraction for implant restorations. However, there exist limited guidelines in gingival retraction for dental implant restorations. Technologies are as such not developed to reduce tissue interference in implant supported restorations.

At present there are no studies to address the influence of soft tissue entrapment on screw loosening in zirconia abutments. This study was conducted to understand influence of tissue entrapment on screw loosening, in titanium/titanium and titanium/zirconia implant abutment systems. The study will bring forth the importance of developing a specific method for tissue retraction in implantology.

2. MATERIALS AND METHODS

All study components were manufactured by ADIN Dental implants Limited (Alon Tavor POB 1128, Afula 1811101, Israel). The following components were used in this study. Twenty 3.5 x 8 mm Adin internal hex implants (IFS 0835), 10 titanium abutments (RS38000) and 10 zirconium abutments (ZA- 0105). Twenty implants were mounted on self-cure acrylic blocks (DPI-RR Cold Cure, Dental Products of India, Delhi, India) of 3x3 cm diameter with the help of dental Surveyor (Marathon Surveyor 103 complete) to ensure the parallelism. Implant/abutment interface were exposed one mm above the acrylic blocks (Figure 1).

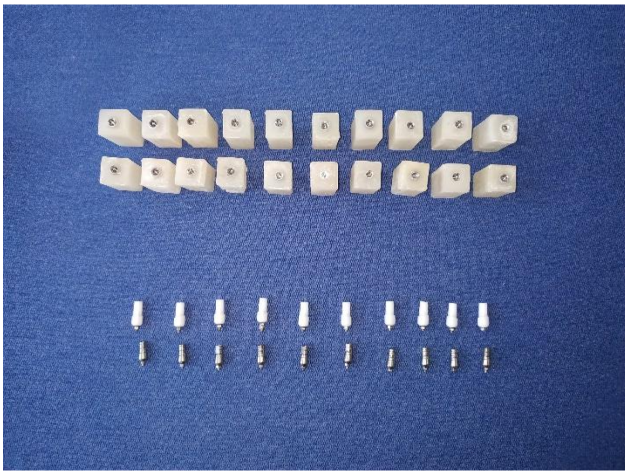

Figure 1. Mounted titanium implants, titanium abutments and zirconium Abutments

Tissue specimen preparation

Soft tissue specimens were collected from the palate of pig with the help of punch biopsy. The samples were then fixed with 10% formalin. Then using a punch biopsy needle of diameter 5 mm, these specimens were punched. The basic structure of the tissue sample was of a disc of 5 mm (millimetre)diameter and 0.5 mm thickness. To standardize tissue thickness of the sample to, 0.5 mm, an aluminium alloy block was fabricated using CAD/CAM (Computer aided design/ Computer aided manufacture) technology with an indentation of 0.5 mm depth. Tissue samples were placed inside the block indentation and polished to a 0.5 mm thickness using a tissue polishing system with a 1200-grit sandpaper. Precise measurements of tissue thickness were recorded using a digital calliper (Mitutoyo 150 mm Digimatic Caliper 500-196-30) to ensure accuracy. A centre punch of 2 mm diameter was made in the sample in order to facilitate the abutment screw through the sample (Figure 2).

Figure 2. Titanium and zirconium abutments with entrapped tissue

Study Groups

Four implant groups (n = 10) were studied. Group 1 Group 2 comprised of Titanium implant/Titanium abutment connections with and without soft tissue respectively. Group 3 and Group 4 consist of Titanium implant/Zirconium abutment connections with and without soft tissue respectively. Group 1 and Group 3 were the test groups and Group 2 and Group 4 were the control groups. The abutments were tightened and torqued to 20 Ncm with the help of a digital torque gauge (Figure 3).

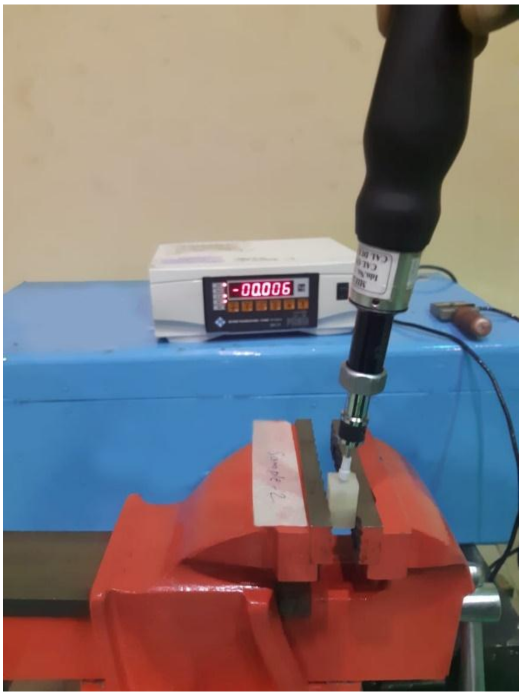

Figure 3. Testing the specimens using digital torque wrench

The Specimens of implant/abutment interface with soft tissue were immersed in 1 M NaOH solution for 48 hours in order to dissolve tissue. This simulated breakdown of tissue in saliva inside the oral cavity. Then reverse torque values were recorded for each sample and each group separately. The tissue entrapment at the implant/abutment connection was assessed by visual inspection. The abutments and tightening screws in each group was then disconnected from the implant bodies. The specimens with tissue were cleaned manually. A second insertion torque was recorded on all specimens using the digital torque limiting device to evaluate the clinical significance of reinsertion of Titanium abutments and Zirconium abutments with entrapped tissue.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences software (IBM SPSS Statistics for Windows Version 20.0, Armonk, NY). Mean and standard deviation were determined for each group for both insertion and reverse torque values. For comparison of reverse torque values at 10 min and 48 hours between Group 1 & 2, Group 3 & 4 and Group 1 & 3; Mann Whitney U test was applied. For all statistical evaluations, a two-tailed probability value p value < 0.05 was considered as significant. The methodology was reviewed by an independent statistician

3. RESULTS

All the titanium and zirconium abutments with and without tissue entrapment, were tightened to 20Ncm. No statistically significant differences ($p < 0.05$) were found among any of the groups ($n = 5$ for groups with tissue entrapment and $n = 5$ control groups) in achieving insertion torque values. The groups with entrapped tissues (test groups) were immersed in 1 M NaOH solution for 48 hours in order to mimic salivary breakdown of tissue inside the oral cavity. However, the test groups did not show any noticeable looseness on the implant abutment interface. Then reverse torque values were measured. Statistically significant variation in reverse torque values were found between all groups with and without tissue entrapment, ($p < 0.05$) (Table 1).

Table 1. Descriptive Statistics

Descriptive Statistics				
Group		N	Mean	S D
Ti test (titanium)	After 10 mins	5	15.7800	.13766
	After 48 hrs(hours)	5	13.8600	.14629
	Reinsertion torque	5	20.0860	.20623
	Loss after 10 min(minutes)	5	4.2200	.13766
	Loss after 48 hours	5	6.1400	.14629
Ti control	After 10 mins	5	16.6440	.88816
	After 48 hrs	5	15.8740	.55801
	Reinsertion torque	5	19.4840	1.15381
	Loss after 10 min	5	3.3560	.88816
	Loss after 48 hours	5	4.1260	.55801
	After 10 mins	5	13.8640	.26035

Zr test (zirconium)	After 48 hrs	5	12.1260	.27727
	Reinsertion torque	5	20.2000	.44317
	Loss after 10 min	5	6.1360	.26035
	Loss after 48 hours	5	7.8740	.27727
Zr control	After 10 mins	5	15.4860	.53956
	After 48 hrs	5	13.4820	.44257
	Reinsertion torque	5	20.0000	.00000
	Loss after 10 min	5	4.5140	.53956
	Loss after 48 hours	5	6.5180	.44257

Mean torque loss for Group I (Test Group: Titanium/ titanium implant abutment interface with tissue) was 15.7800 Ncm and for Group 2 (Control Group: Titanium/ titanium implant abutment interface without tissue), it was 16.6440 Ncm after 10 minutes. After 48 hours the mean torque loss for Group 1 was13.8600 Ncm and for Group 2, it was 15.8740 Ncm. Comparison of group 1 and group 2 showed statistically significant variation in reverse torque values, which in turn depicted that tissue entrapment has a significant role in torque loss ($p < 0.05$) (Table 2).

Table 2. Comparison of Ti test and Ti control (Mann Whitney U test) Group 1 and Group 2.

Time Interval	Study Groups	Mean ± SD Torque loss (Ncm)	p value	Z value
10 minutes	Group 1 (n=5)	15.780 ± .137	0.009*	-2.619
	Group 2 (n=5)	16.644 ± .888		
48 hours	Group 1 (n=5)	13.860 ± .146	0.009*	-2.611

*p significant at less than 0.05

Mean torque loss for Group 3 (Test Group: Titanium/ zirconium implant abutment interface with tissue) was 13.8640 Ncm and for Group 4 (Control Group: Titanium/zirconium implant abutment interface without tissue), it was 15.4860 Ncm after 10 minutes. After 48 hours the mean torque loss for Group 3 was 12.1260 Ncm and for Group 4, it was 13.4820 Ncm. The comparison between group 3 and group 4 showed statistically significant variation in reverse torque values, which again denoted the significance of tissue entrapment on torque loss ($p < 0.05$) (Table 3).

Table 3. Comparison of Zr test and control (Mann Whitney U test) Group 3 and group 4

Time Interval	Study Groups	Mean ± SD Torque loss (Ncm)	p value	Z value
10 minutes	Group 3 (n=5)	13.864 ± .260	.009*	-2.611
	Group 4 (n=5)	15.486 ± .539		

48 hours	Group 3 (n=5)	12.126 ± .277	.009*	-2.611

*p significant at less than 0.05

Among the test groups, the mean reverse values of titanium abutments with tissue (Group 1) were 15.78 Ncm after 10 minutes of insertion and 13.86 Ncm after 48 hours, and Zirconia abutments with tissue (Group 3) are 13.86 Ncm after 10 minutes of initial torque and 12.12 Ncm after 48 hours (Figure 4). The comparison between the zirconium and titanium abutments with tissue entrapment showed p value of 0.009 which was statistically significant (Table 4).

Table 4. Comparison of Ti test and Zr test (Mann Whitney U test) Group 1 and Group 3

Time Interval	Study Groups	Mean ± SD Torque loss (Ncm)	p value	Z value
10 minutes	Group 1 (n=5)	15.780 ± .137	0.009*	-2.619
	Group 3 (n=5)	13.864 ± .260		
48 hours	Group 1 (n=5)	13.860 ± .146	0.009*	-2.611

*p significant at less than 0.05

When the loss of torque values (Group 1) and (Group 3) were compared, it was noticed that titanium implant/zirconia abutment with entrapped tissue had more torque loss.

Among the control groups, the mean torque loss for Group 2 was 16.6440 Ncm and for Group 4, it was 15.4860 Ncm after 10 minutes. After 48 hours the mean torque loss for Group 2 was 15.8740 Ncm and for Group 4, it was 13.4820 Ncm. The comparison between group 2 and 4 showed statistical significance only after 48 hours ($p < 0.05$) (Table 5). When the loss of torque values of (Group 2) and (Group 4) was compared, it was noticed that titanium implant/zirconia abutment without entrapped tissue had more torque loss. Mean reverse torque values of test and control groups are shown in (Figure 4).

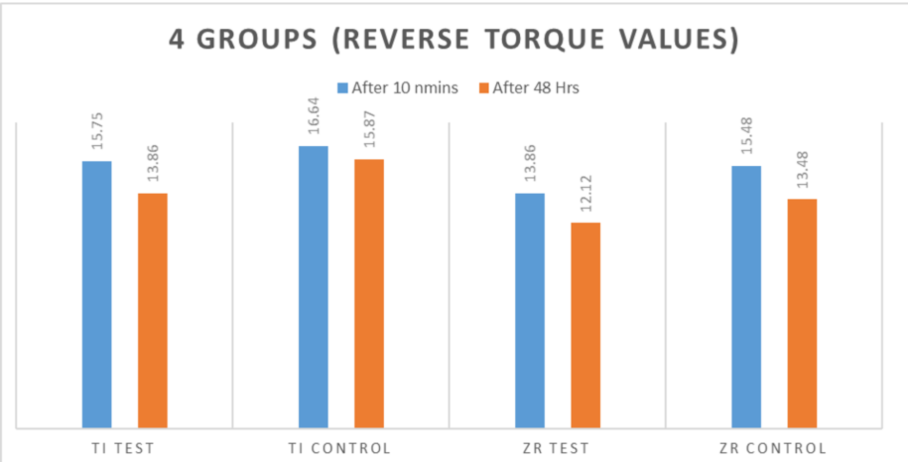

Figure 4. Mean reverse torque values of test and control groups

4. DISCUSSION

The present study was conducted to answer the research question, does tissue entrapment between the interface of implant abutment connection of Titanium and Zirconium abutments result in decrease of reverse torque values? The null hypothesis was that, entrapment of gingiva does not have any effect on torque loss/screw loosening between the interface of abutment/implant of Titanium and Zirconium abutments.

In order to assess the nature of torque loss due to entrapment of tissue, insertion torque values were measured, in all the groups with and without tissue. Control groups as well as the test groups, insertion torque values were achieved to 20 Ncm. Torque drop were recorded following 10 minutes and 48 hours. Prior to assessment of loss in torque, to mimic salivary breakdown of tissue inside the oral cavity the specimens with entrapped gingival tissue were immersed in 1 M NaOH solution for 48 hours.

Group 1 and group 2 were compared for torque loss, maximum torque loss was associated with, the specimens with entrapped tissue. Maximum mean torque (13.86 Ncm) was noticed for group 2 following 48 hours. When the test groups (Group 1 and group 3) were compared it was noticed that, maximum mean torque loss (12.12 Ncm) was associated with titanium zirconium implant abutment interface with tissue, following 48 hours. Data analysis of the study revealed that, tissue entrapment significantly contributes to torque loss. Similarly, when Group 3 and Group 4 were compared, maximum torque loss was associated with specimens with tissue. Maximum mean torque loss (12.12 Ncm) was noticed following 48 hours. When the control groups (Group 3 and group 4) without tissue were compared, it was observed that titanium zirconium implant/abutment surface showed maximum torque loss, again after 48 hours.

Screw mechanics and prosthetic failure

Passive fit of restorations and abutment are considered as one of the most significant requirements for maintaining bone level [12-14]. To achieve passive fit, the frame work should impart zero strain on the implant/ abutment interface in the absence of functional load. This requirement may be achieved by simultaneous and even contact of the complete inner surfaces of implant and the abutment [15].

Entrapment of gingival tissue prevent this even mating of implant/abutment interface. To a great extent the magnitude of force on the implant, the mechanical integrity of the interface and the strength and stability of joint are determined by the design of implant/ abutment connection [2].[16]. Screw loosening and fracture of abutment screw depends on the type of implant abutment design. It also influences, how the loads are transferred to the implant bone interface and to the implant prosthetic interface. According to the current scientific evidence and with the efficacy of current dental technology used for the fabrication of frame work, it has been concluded that a complete passive fit is not achievable [17].[18]. Prosthetic failures such as screw loosening or fracture may result from poor framework fit [19-23].

According to Mc Glumphy et al. the screw joint is considered as two components clamped together by a screw. Abutment and implant are held together by a screw [2]. A specified torque is applied to tighten the screw. This create a preload which results in compressive stresses, as the implant and abutment are tightened together [24]. Forces attempting to separate the parts are called joint-separating forces. These forces must remain below the threshold of the established preload. The applied torque or preload is achieved, based on variables such as the physical properties of materials in contact, presence of lubricants, settling of screw and the initial torque applied [8]. As torque is applied to the abutment screw, the screw elongates and keep the screw body in tension [8]. Elastic recovery of the abutment screw creates a clamping force which pulls the implant and prosthesis together [9].

Abutment screw loosening results from the deformation of the screw and connected members in response to an external load applied [25]. Though 20 Ncm insertion torque values were achieved by all the groups with and without soft tissue, higher torque loss values were associated with groups with tissue entrapment. This could have happened because of uneven contact between the contacting surfaces of implant abutment connection resulting in subsequent torque loss.

When occlusal loads are applied to the implant crown, the screw head get compressed is symmetrically and reduces the frictional forces between implant and abutment. As the preload decreases, the threads disengage and the screw loosening occur [26].[27]. Studies have demonstrated that insufficient preload or under tightened abutment screws depicted greater micro movement in the implant/abutment interface, that leads to loosening of screw, failure of joint and prosthesis. Settling effect of screws plays a vital role in screw stability.

Under functional loads the rough spots on the mating surfaces of implant and abutment get flattens leading to screw settling. During the initial tightening, the rough points meet and they will be the only contacting surfaces [29]. It was found that 2% to 10% of the initial torque applied is lost due to settling of screw. Hence the torque required to remove an abutment screw is less than the torque used initially to tighten the screw [30]. Entrapped tissue between implant and abutment also result in reduction of initial contact of rough spots. The design and geometry of the joint also contribute in stability of the implant abutment connection. Various authors have proposed that loss of torque has significant influence on screw loosening [1].

Implant/abutment joint success is accomplished by achieving optimum preload of the interface. This will maximize the fatigue life of the abutment screw while offering a reasonable degree of protection against loosening [7]. Specific amount of torque that should be applied to the screw is decided by each manufacturer. Fatigue testing studies have been conducted on implant/ abutment systems revealed that reduced reverse torque values can lead to screw loosening. To maintain a stable implant/abutment joint an accurate interface, free of irregularities on the contacting surfaces, is necessary. The maintenance of a clean implant/abutment interface during clinical procedures such as metal trial and final delivery is essential for accurate seating of the restoration. Tissue entrapped at the abutment/implant interface undergo ischemia and subsequent necrosis, thereby creating a space between the implant abutment interface. This space at the abutment/implant connection could lead to decreased preload of the abutment screw.

Screw loosening and tissue entrapment

Tissue entrapment is one of the major factors which causes improper seating of the abutment [31]. The tissue, which gets entrapped between the implant abutment interfaces causes hindrance to the abutment and fails to get a proper contact between the surfaces of the implant body and abutment. The tissue entrapped may act as a spacer. This can lead to the diminished contact area. In spite of giving a 20 Ncm insertion torque to the head of the abutment screw, tissue entrapment may create a lowered initial preload than the optimal manufacturer recommendation of the screw joint [9]. Entrapped tissue undergoes degeneration over a period of time. This results in formation of micro gaps between the implant and abutment. This study revealed that tissue entrapment at the implant abutment interface created decreased reverse torque values.

The data from the study clearly reveal the effect of tissue entrapment on torque loss of implant abutment interface of two-piece implants. The study also reveals the effect of difference in abutment materials on torque loss at the implant abutment interface. By analysing the reverse torque values of 20 samples, the values after 10 minutes of initial torqueing and 48 hours after initial torqueing, it was noticed that, soft tissue entrapment resulted in significant reduction in reverse torque values. The values also showed that zirconium abutments have more loss of torque when compared to titanium abutments.

5. CONCLUSION

This study focussed on evaluating the effect of gingival tissue entrapment on abutment screw loosening at the implant abutment connection of titanium and zirconium abutments. Within the limitations of the study, followings conclusions were drawn;

1. Tissue entrapment along the implant/abutment interface results in significant reduction in torque values following 10 minutes and 48 hours both in zirconium and titanium abutments.
2. Zirconium implant/abutment interface with tissue entrapment showed higher torque loss compared to titanium implant/abutment interface with soft tissue.

3. The study also revealed that the Zirconium abutments showed significant reduction in torque values when compared to titanium abutments with and without soft tissue entrapment.

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