Comparison of effect of mechanical loading on reverse torque value of straight and angulated prosthetic abutment in regular platform dental implant: an in-vitro study.

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Abstract: Background and objective: Loosening and breaking of the screws that secure the prosthesis to the implant is a frequent issue with the use of dental implants for prostheses. Our objective was to assess the effect of mechanical loading on the reverse torque value of prosthetic abutments in regular-platform dental implants, namely, those that were angulated or straight.

Methodology: The sample size of 12 was divided into two groups: a) implant analog with an angulated prosthetic abutment (Group A) and b) implant analog with a straight prosthetic abutment (Group B), with six abutments in each group, resulting in 12 implant-abutment assemblies mounted onto an acrylic resin block (15 mm diameter ×15 mm height). 1,00,000 cycles of mechanical loading were applied, then the reverse torque value (RTV) ratio was calculated before and after loading, tabulated, and analyzed. Intergroup comparisons between groups for the study parameters were performed using an unpaired t-test.A paired t-test was used for intragroup comparisons within each group from the pre-to post-study findings.

Results: The results of this study showed that the initial screw loosening process occurred in both angulated and straight prosthetic abutments, but screwing loosening post-load occurred more frequently in group A. This could be because the loading on angled abutments is mostly off-axis. The initial and post-load RTV in Group A highly significant ($p<0.001$)whereas for Group B, the initial and post-load RTV were non-significant ($p=0.039$). The percentage difference between the initial and post-load RTV for Group A and Group B was highly significant ($p<0.001$).

Conclusion: It has been noted that screw loosening increased with increasing abutment angulations, and Higher RTVs were observed after loading straight prosthetic abutments after exposure to 1,00,000 cycles of the chewing simulator.

Keywords: Cyclic loading, removal torque value, screw loosening, Dental abutments.

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Introduction:- The turn of the century marked the advent of a new era in prosthodontics, characterized by the explosive advancement of oral implant technology. The introduction of implant technology has significantly enhanced the quality of life of patients by drastically improving the cosmetic and functional outcomes of definitive restorations compared with traditional methods. This advancement has expanded the number of options available to both clinicians and patients. Despite its numerous benefits, implant technology is not without flaws. The clinical practice of implant-supported restorations faces challenges, such as surgical trauma, high costs and prolonged treatment duration. Additionally, biological and mechanical complications, including peri-mucositis, peri-implantitis, loosening or fracturing of the abutment screw, fracturing of the abutment or superstructure, crown loosening, and porcelain cracking, pose significant concerns.[1]

In two-piece implant systems, there are two primary types of implant-abutment connections: external and internal. An external connection is characterized by a hexagonal or octagon structure, 1-2 mm in height protruding from the top of the implant to connect with the abutment. Conversely, an internal connection involves an abutment that extends 4-6 mm into the implant.[2]

A prevalent issue in the use of dental implants for prosthetics is the loosening and fracturing of the screws that secure the prosthesis to the implant.[3] Factors contributing to screw loosening include the settling effect, excessive bending, vibrating micro movement, fatigue, and insufficient tightening torque,[4] Various elements related to screw design and fabrication can influence the loosening of abutment or prosthetic screws in metal-to-metal screw systems. These factors primarily include the preload, components and screw material, manufacturer's quality control, screw joint design, surface roughness, and inappropriate tightening torque. Among these, inadequate tightening torque has been reported to be the main factor leading to screw loosening. Retightening of the implant abutment screw is highly recommended to mitigate the risk of screw loosening. Retightening the screws ten minutes after the initial tightening was the most effective strategy. Retightening also reduces the settling effect with a minimal impact on the preload, with the effect being more pronounced at high coefficients of friction.[5]

This in vitro study was conducted to compare the effect of mechanical loading on the reverse torque value (RTV) of angulated and straight prosthetic abutments in regular-platform dental implants. The null hypothesis tested was that there would be no significant differences between the initial and post-load reverse torque values before and after mechanical loading between angulated and straight prosthetic abutments.

Materials and Methods: This study used 12 implant fixtures (Genesis, India) equipped with either angulated or straight prosthetic abutments. These fixtures were divided into two groups, each containing six implants (n=6): Group A angulated prosthetic abutments and Group B with straight prosthetic abutments (Figure 1). The implants were embedded into acrylic resin within a cylindrical silicon mold measuring 15 mm in height and 15 mm in diameter. De Carvalho et al. stated that acrylic resin is suitable for cyclic loading tests owing to its adequate flexural strength. Its modulus of elasticity (3.4×10^5 lb/in²) closely resembles that of cancellous bone (3.6×10^5 lb/in²).

In this study, a torque of 25 Ncm was applied to both angulated and straight prosthetic abutments, according to the manufacturer's recommendations. After the initial tightening, the specimens were re-tightened after 10 min. The initial removal torque value (RTV) was measured using a high-resolution Lutron Digital Torque Meter (Figures 2 and 3) before subjecting the specimens to cyclic loading. Subsequently, the specimens in both Group A and Group B were re-tightened to the manufacturer's recommended torque of 25 Ncm after a 10-minute interval. The retightened specimens were then mounted on an S-D Mechatronik chewing simulator (Figure 4) for cyclic loading. After cyclic loading, the post-load removal torque (RTV) was measured. A vertical load was applied to the center of the abutment using a chewing simulator, with 100,000 cycles of mechanical loading corresponding to one month of the masticatory cycle (Figure 5).

Calculation of removal torque loss (RTL) ratio of abutment screw before and after dynamic cyclic loading (DCL)[2]

Loss ratio of removal torque before loading (%) = Tightening torque – initial removal torque value × 100 Tightening torque

Loss ratio of removal torque after loading (%) = Tightening torque – post load removal torque value × 100 Tightening torque

Loss ratio of removal torque between before and after loading (%) = initial removal torque value – post load removal torque value × 100 Initial removal torque value

Data analysis: Statistical analysis was performed using Statistical Package for Social Science (SPSS) version 21 for Windows (SPSS Inc, Chicago, IL). Intergroup comparisons between groups for the study parameters were performed using an unpaired t-test. A paired t-test was used for intragroup comparisons within each group from the pre-to post-study findings. Statistical significance was set at $p < 0.05$.

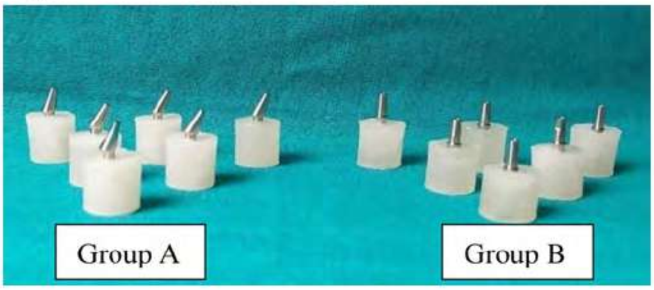

Figure 1: Grouping of specimens From left Group A Angulated prosthetic abutments to right Group B Straight prosthetic abutment.

Figure 2: Digital torque meter (Lutron Electronic Enterprises Co. Ltd. Taiwan)

Figure 3: Applying a 25Ncm torque on angulated and straight prosthetic abutment.

Figure:4 Chewing simulator

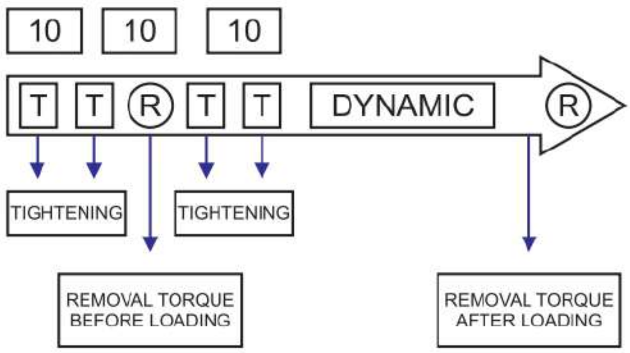

Figure:5 Diagrammatic arrow represents the procedure

Results: The initial removal torque values (RTV) for Group A and Group B were 20.55 ± 0.85 Ncm and 21.73 ± 1.82 Ncm, respectively (Table 1). The initial RTV percentages for Groups A and B were 17.8 ± 3.4% and 13.06 ± 7.3%, respectively.

Post-load RTV measurements revealed that Group A had a mean RTV of 16.63 ± 1.2 Ncm, while Group B had a mean RTV of 26.35 ± 4.39 Ncm (Table 2). The post-load RTV percentages were 33.46 ± 4.8% in Group A and -10.06 ± 19.68% in Group B. The mean percentage difference between the initial and post-load RTV was 18.96 ± 5.58% for Group A and -29.75 ± 22.8% for Group B (Figure 6). This difference was statistically significant ($p < 0.001$).

No significant difference was observed in the initial RTV between Group A and Group B ($p = 0.181$). Additionally, there was no significant difference between the initial and post-load RTV for Group B ($p = 0.039$). However, a highly significant difference was noted in the post-load RTV between Group A and Group B, as well as in the initial and post-load RTV for Group B ($p < 0.001$).

Table: 1 Comparison between initial and post-load removal torque values for Group A and Group B

Groups	Initial RTV	Post load RTV	Difference between initial and post-load torque loss	Paired t test	P value, Significance
Group A (Angulated)	20.55±0.85	16.63±1.2	3.91±0.6	t= 6.507	P<0.001**
Group B (Straight)	21.73±1.82	26.35±4.39	-4.61±1.94	t= -2.378	p = 0.039*

p>0.05 – no significant difference

*P< 0.05 – significant

**p<0.001-highly significant

Table: 2 Comparison of initial and post-load removal torque loss for Group A and Group B

Removal torque loss	Group A (Angulated)	Groups B (Straight)	Mean difference between initial and post-load torque loss	Unpaired t- test	P value, Significance
Initial	17.8 ±3.4	13.06 ±7.3	4.73 ±3.29	t= 1.438	p= 0.181
Post load	33.46 ±4.81	-10.06 ±19.68	43.53 ±8.27	t= 5.261	p < 0.001**
Percentage difference between initial and post load	18.96±5.58	-29.75±22.8	48.71± 9.58	t = 5.083	p< 0.001**

p>0.05 – no significant difference

*P< 0.05 – significant

**p<0.001-highly significant

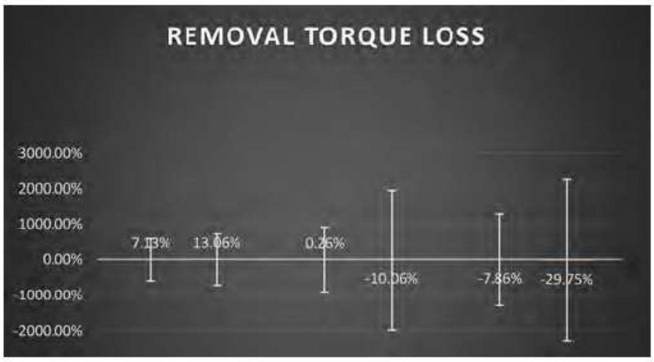

Figure 6: Intergroup comparison of before and after loading also difference ratio before and after removal torque

Discussion: Efforts to mitigate common challenges associated with treatment and enhance the survival rates of implants, abutment screws, implant-abutment connections, and superstructures persist in the dental implant field. Consequently, clinicians must be aware of the forces exerted on the screw joint to minimize or forestall screw loosening and related complications.[5,6]

A torque was applied to tighten the abutment screw, generating a preload that represents the force induced in the screw by the applied torque.[7] This preload corresponds to the tension exerted when tightening an abutment screw, directly influencing the clamping force. As the screw is tightened, tension is engendered in both the abutment screw and the implant surface, leading to elongation of the screw. Subsequently, the elastic recovery of the screw draws the two components together, akin to the clamping force generated by a rubber band.[7] Concurrently, joint separating forces, which strive to disengage components, are operative.[5]

Conversely, compressive stresses arise at the implant abutment interface and are governed by three key factors: machining tolerance, settling effect, and wedge effect. Machining tolerance encompasses surface roughness and dimensional variation, intrinsic to machined implant components. The settling effect occurs between two rough surfaces, where adhesive wear causes flattening of rough patches under pressure, resulting in closer proximity of the surfaces. Internal (INT) and external (EXT) connections are susceptible to this phenomenon. Notably, the wedge effect, which is more pronounced in the INT connection, involves the abutment acting as a wedge, concentrating the axial compressive forces in the direction of abutment insertion. This amplifies the frictional resistance and contact pressure, with the wedge effect escalating alongside the tightening torque.(8)

Thus, the primary factors implicated in maintaining the tightness of implant screws entail maximizing the clamping force while minimizing the joint separating forces. Notably, it is posited that 2–10% of the original preload may be forfeited due to the settling effect, constituting one of the principal mechanisms of screw loosening in implant-supported restorations, along with excessive bending of the screw joint in the direction of the applied load.(9)

The optimal torque value for screw tightening is recommended as 75% of the torque necessary to induce screw failure.(10,11) Bickford delineated the process of screw loosening into two distinct stages. During the initial tensile deformation phase, external forces primarily impacted the screw, leading to a reduction in the clamping force. Consequently, external forces act in opposition to the original tightness of the screw, causing slight stretching and subsequent diminishment of the clamping force.(12)

Subsequently, in the second stage, as the clamping force further decreases upon application of force, micromotion at the implant-abutment interface intensifies, fostering instability at the connection and subjecting the screw surface to stress, thereby precipitating screw loosening. The loss of preload due to the application of external force results in abutment screw loosening.(1)

Angled abutments facilitate the rehabilitation of implants positioned in buccolingual or mesiodistal misalignments, with prefabricated abutments angled by 25°, facilitating parallelism between adjacent abutments. Moreover, correction of implant trajectory using a 25° angled abutment may displace the restoration by two–three millimeters at the occlusal aspect. However, angulated abutments, employed in scenarios where axial or conventional positions are untenable owing to anatomical or biological factors, are susceptible to non-axial forces that transfer adverse forces to the implant and bone, potentially compromising treatment prognosis.(13,14)

In this study, abutment screws were tightened to 25 cm using a digital torque gauge according to the manufacturer's instructions. Following the initial torque application, a ten-minute interval elapsed. Subsequently, using the same digital torque gauge, all screws were retightened to an identical tightening torque (25 Ncm) to compensate for the preload loss attributable to the screw's settling effect. This approach ensured the attainment of an optimal preload, whereby only 10% of the initial torque was converted into preload, with the remaining 90% utilized to surmount friction between surface irregularities.(2)

A vertical load simulating masticatory forces was applied at the central point of the abutment by using a chewing simulator. Each chewing cycle entailed downward vertical movement lasting 1 s, amounting to 60 cycles per minute (1 Hz), with a masticatory load of 50 N. Notably, the average daily number of mastications is approximately 2,700, and 100,000 cycles correspond to approximately one month.(15,16)

The study findings revealed the occurrence of screw loosening in both Group A and Group B, attributed to distinct angulations of the prosthetic abutments. Initial mean RTV following tightening torque application of 25 Ncm for Group A and Group B amounted to 20.55 ± 0.85 Ncm and 21.73 ± 1.82 Ncm, respectively, with percentage losses of 17.8 ± 3.4% and 13.06 ± 7.3% for Group A and Group

B. Subsequent post-load RTV for Group A recorded 16.63 ± 1.2 Ncm with a percentage loss of 33.46 ± 4.81%, while for Group B, it measured 26.35 ± 4.39 Ncm with a percentage gain of -10.06 ± 19.68%.

The post-load RTV for Group A, characterized by a percentage loss of 33.46 ± 4.81%, underscores the exacerbation of off-axis forces with increasing angulation, imposing additional stress and strain on the implant components, particularly the screw. Off-axis loading engenders a threefold or greater amplification in the stress magnitude on the implant, correlating with the rise in abutment angulation and a statistically significant increase in strain and stress. This underscores the importance of mitigating excessive off-axial and occlusal stress in implant-supported restorations.

The clinical loading of implants restored with angled abutments may precipitate augmented lateral occlusal stresses, potentially inducing torsional forces and consequent screw loosening. Any load vector diverging from the implant's long axis accentuates crestal stresses on the abutment screws of the restoration and the implant-bone interface.[2]

Similarly, Group B exhibited a post-load RTV percentage gain of -10.06 ± 19.68%. Conversely, the straight prosthetic abutment demonstrated a positive effect owing to its broader diameter, increased surface area, and augmented material thickness, thereby mitigating the stress concentration at the implant-abutment junction. Notably, a significant percentage gain in the reverse torque value following cyclic loading was observed in Group B. This phenomenon has been attributed to the settling effect, also known as "embedment relaxation," which transpires when rough contact points flatten under load. The study's findings and data advocate for the utilization of angulated prosthetic abutments in scenarios characterized by misalignment or suboptimal implant positioning, whereas straight prosthetic abutments are recommended when forces are maximal.[15]

Conclusions: Within the scope and limitations of this study, the following conclusions were drawn:

1 The initial process of screw loosening transpired in both Group A (Angulated prosthetic abutment) and Group B (Straight prosthetic abutment).

2 Group B (straight prosthetic abutment) exhibited higher reverse torque values (RTVs), indicating a greater percentage gain after exposure to 100,000 chewing simulator cycles.

3 The percentage difference between the initial and post-load RTVs manifested as a percentage loss in Group A (angulated prosthetic abutment), indicating a higher propensity for screw loosening. Conversely, Group B (straight prosthetic abutment) showed a percentage gain, indicative of a diminished incidence of screw loosening.

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