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Determinants Of Abutment Screw Loosening In Dental Implants: A Review

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Abstract

Dental implants have become a highly successful treatment modality for restoring partial and complete edentulism, with long-term survival rates exceeding 90%. However, mechanical complications—particularly abutment screw loosening—continue to challenge clinicians and compromise prosthesis stability. This review explores the biomechanical and material determinants influencing abutment screw stability in dental implants. Key factors such as implant–abutment connection design, retightening protocols, functional loading, component dimensions, and screw surface modifications were analysed from current literature. Evidence indicates that internal and Morse taper connections provide superior preload maintenance due to enhanced mechanical interlocking. Timely retightening, especially within 5–10 minutes after initial torque, compensates for preload loss from embedment relaxation. Controlled cyclic loading, larger abutment dimensions, and the use of coated or surface-modified screws further improve joint stability by optimizing stress distribution and reducing frictional losses. Collectively, these findings highlight the importance of evidence-based torque and maintenance protocols to minimize screw loosening and enhance the long-term success of implant-supported prosthesis.

Keywords: *Dental Implants; Abutment screw loosening; Preload; Torque loss; Biomechanical stability*

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I. Introduction

Dental implants have revolutionized the rehabilitation of partially and completely edentulous patients by offering a predictable, functional, and esthetic solution. Since the introduction of osseointegration by Brånemark in the 1960s, implant-supported prostheses have shown long-term survival rates exceeding 90% over ten years [1]. Despite such success, mechanical complications continue to challenge clinicians, with abutment screw loosening being one of the most frequently encountered problems in implant prosthodontics [2].

The implant–abutment complex plays a crucial role in ensuring the mechanical integrity and biological seal of the prosthetic assembly. The connection between the implant and abutment is secured by a screw that generates a preload—a clamping force that holds the components together. This preload resists the separating forces generated during mastication and other functional movements. [3,4] Loss of this preload can lead to abutment micromovement, marginal gaps, and prosthesis instability, eventually causing mechanical failure or peri-implant bone loss [5].

The magnitude of preload depends primarily on the applied torque and the frictional characteristics of the contacting surfaces. However, even when the manufacturer-recommended torque is applied, a portion of the preload is inevitably lost due to microscopic flattening of surface irregularities at the screw–abutment interface, a phenomenon known as *embedment relaxation*.[6,7] Studies have reported that 2–10% of the initial preload may be lost within minutes after tightening, increasing further under cyclic functional loading [8].

Over time, researchers have identified several factors influencing the stability of the implant–abutment junction. Among these, connection design, tightening and retightening protocols, loading conditions, dimensional characteristics of implant components, and surface modifications of the screw have received particular attention[9,10]

II. Rationale And Need For The Review

Despite the widespread clinical success of dental implants, mechanical complications—particularly screw loosening—remain prevalent. These complications compromise the long-term stability of implant prostheses and patient satisfaction. While numerous studies have addressed isolated factors affecting screw stability, a comprehensive understanding of their collective influence is essential for evidence-based clinical protocols.

This review seeks to synthesize existing literature on the biomechanical and material determinants of abutment screw stability, analyzing the roles of connection design, retightening intervals, loading dynamics, component dimensions, and surface coatings. Understanding these parameters will help clinicians adopt optimized tightening protocols, select appropriate implant systems, and improve long-term clinical outcomes.

III. Determinants Of Abutment Screw Loosening In Dental Implants

Influence of Implant–Abutment Connection Design

The design of the implant–abutment connection is a critical determinant of the long-term mechanical stability and biological integrity of implant-supported restorations. The interface between the implant body and abutment serves as both a mechanical junction and a potential site for microbial leakage. Over the years, numerous connection designs—external hexagonal, internal hexagonal, conical, and Morse taper—have been developed to enhance stability and minimize mechanical complications such as screw loosening, micro-movement, and fracture.

Weiss et al. (2000) [11] investigated the effect of implant design on torque loss and microleakage. They reported that internal connection systems provided superior resistance to micromovement and torque loss compared to external hex designs. The Morse taper connection, in particular, demonstrated the best mechanical interlocking and minimal microgap formation due to its self-locking conical geometry.

Saber et al. (2014) [12] compared the fatigue resistance of internal conical and internal hexagonal connections and found that the conical interface retained higher reverse torque values after cyclic loading, suggesting better preload maintenance . The wedging action of the conical fit improved the stress transfer and minimized screw loosening.

Collectively, the evidence indicates that internal and Morse taper designs provide mechanical superiority over external hex systems by reducing micromovement, improving stress distribution, and minimizing microleakage.

Effect of Retightening Intervals and Timing Protocols

The stability of the implant–abutment joint depends not only on connection design but also on the timing and frequency of torque application. "Settling" or "embedment relaxation" occurs as microscopic irregularities between contacting surfaces flatten under load, leading to a reduction in preload. Timely retightening compensates for this loss and ensures long-term stability.

Varvara et al. (2013) examined the influence of different retightening intervals on abutment screw preload (3)[13]. Their results showed that 2 minutes after retightening reduced the settling effect, resulting in improved preload maintenance. Delayed retightening, allowed more relaxation and preload loss. The study emphasized that clinicians should perform an additional tightening step shortly after the initial torque to restore the intended preload.

Kim et al. (2011) [14] evaluated the effect of repeated tightening on various connection configurations, including external butt-joint and internal hexagonal or octagonal systems . All connection types exhibited measurable settling after the first tightening; however, retightening at a 10-minute interval effectively stabilized the preload. The internal hexagon two-piece design demonstrated the highest settling values, while the external butt-joint had the lowest.

Kopplin et al. (2014) [15] compared indexed and non-indexed abutments in Morse taper systems which is inserted at an interval of 10 minutes, . They found no significant differences between the two groups in overall stability, but indexed abutments exhibited a greater percentage reduction in reverse torque (15.3 %) than non-indexed abutments (8 %). The results implied that the presence of an anti-rotational index could increase micro-movements and subsequent torque loss.

Alnasser et al. (2021, 2023) [16,17] conducted two sequential studies on delayed retightening. In 2021, they demonstrated that retightening after cyclic loading partially restored lost preload, while their 2023 study confirmed that retightening 5–10 minutes after initial torque significantly improved reverse torque values.

These findings confirm that delayed retightening protocols are effective in compensating for preload loss and should be routinely performed in clinical practice.

Impact of Functional Loading on Screw Stability

Functional and parafunctional forces acting on implant restorations lead to micro-movements and cyclic loading at the screw joint, progressively diminishing the applied preload. Understanding how different loading conditions influence screw stability is fundamental to designing durable implant assemblies.

Khraisat et al. (2004) [18] examined the influence of loading direction—centric versus eccentric—on reverse torque values . They found that centric loading resulted in significantly greater torque loss than eccentric lateral loading or unloaded control samples. The authors suggested that eccentric loading distributed stresses more evenly, preserving preload and reducing micro-movement at the interface. This finding indicated that occlusal design and load direction are vital determinants of screw stability.

Permatti et al. (2012) [19] further explored the influence of dynamic cyclic loading on abutment screw stability. They demonstrated that torque loss was directly proportional to the magnitude and frequency of cyclic loading. However, applying retightening intervals during the loading process significantly reduced preload loss, confirming the importance of maintenance protocols during prosthetic follow-up.

Coppedè et al. (2013) [20] conducted a mechanical fatigue analysis of implant–abutment assemblies subjected to repeated functional loads . Their findings revealed that all connection types experienced a gradual reduction in preload under mechanical cycling. Nevertheless, the Morse taper interface retained higher torque values than external hex systems, illustrating the advantage of frictional locking in resisting mechanical fatigue.

Cho et al. (2015) [21] compared the performance of internal and external connections under cyclic loading at a 30 Ncm torque . Reverse torque values decreased in all groups after mechanical cycling; however, external type implants maintained higher torque retention both before and after loading. Early retightening cycles—particularly for internal connections—were shown to mitigate the reduction in preload. The authors recommended performing early-stage screw retightening, especially in internal connection systems, to enhance long-term mechanical stability.

Ebadian et al. (2021) [22] evaluated the effect of different torque application protocols—single torque, repeated torque, and increased torque magnitude—on reverse torque values . The group that received a single torque of 35 Ncm showed the highest detorque values after mechanical cycling, whereas multiple torque cycles led to greater preload loss. These findings suggest that while retightening is beneficial, excessive tightening or over-torquing can cause micro-damage and accelerate settling.

Vinhas et al. (2019) [23] corroborated that cyclic functional loading remains the principal factor contributing to preload reduction . They observed that the frequency and direction of occlusal forces significantly influenced torque loss, and emphasized that periodic maintenance torque applications combined with material optimization could reduce this effect. The study concluded that controlled functional loading and regular follow-up retightening are crucial for ensuring the mechanical reliability of implant–abutment joints.

Influence of Implant Component Dimensions

The dimensions of implant and abutment components, including abutment height, platform diameter, and wall thickness, determine the magnitude and direction of stress transferred to the screw joint.

Guo et al. (2016) [24] evaluated the relationship between abutment height, diameter, and torque maintenance (14). Their results indicated that increasing abutment height and using larger platform diameters improved preload retention by reducing bending moments and enhancing axial load distribution. Shorter abutments showed higher stress concentrations, leading to accelerated torque loss and potential mechanical failure.

Lee et al. (2018) [25] conducted a comparative study on narrow-diameter versus standard-diameter abutments and concluded that Narrow-diameter components were more susceptible to torque loss due to their reduced cross-sectional area, which increased stress concentration at the screw neck. The study highlighted the need for cautious prosthetic planning when using narrow platforms, particularly in areas of high functional demand. These findings suggest that larger component dimensions help dissipate occlusal stresses more efficiently, thereby preserving preload and reducing the incidence of mechanical complications.

Effect of Screw Replacement versus Retightening

Clinicians often replace abutment screws when signs of wear or loosening are detected. However, the biomechanical consequences of replacing versus retightening the original screw remain an area of investigation.

Attiah et al. (2020) [26] compared these two approaches and found that retightening existing screws resulted in better preload maintenance than replacing them after cyclic loading. Their study found that the removal torque loss ratio was higher in groups where screws were replaced compared to those that were retightened. Retightening proved more effective than replacement in both standard-diameter and narrow-diameter implants. The authors explained that used screws adapt better to surface irregularities, enhancing frictional resistance and stability. They recommended screw replacement only in cases of visible deformation or corrosion.

This finding holds clinical significance by reducing unnecessary screw replacements and emphasizing the importance of controlled retightening to maintain joint integrity.

Influence of Surface Modification and Coating Characteristics

Surface characteristics of abutment screws—including roughness, coating type, and frictional coefficient—greatly influence preload generation and torque maintenance. Reducing friction at the screw–abutment interface enhances the transfer of applied torque into useful preload rather than dissipating it through surface resistance.

Squier et al. (2002) [27] investigated the effect of surface coatings such as titanium nitride and diamond-like carbon on the mechanical performance of abutment screws . Coated screws demonstrated significantly higher preload and reduced settling effects compared with uncoated titanium screws. The coatings acted as lubricants, lowering the coefficient of friction and allowing more efficient torque conversion into preload.

Byrne et al. (2011) [19] further confirmed that surface-modified screws exhibited enhanced torque transfer consistency and superior corrosion resistance. The study emphasized that surface treatments improve not only mechanical performance but also chemical stability, thereby reducing potential degradation at the implant–abutment junction.

Nigro et al. (2014) [28] explored the influence of various surface finishing techniques on screw preload . They observed that surface-treated screws maintained higher torque retention and generated greater preload compared with untreated ones. Lower friction coefficients enabled more predictable torque application and decreased the likelihood of loosening.

Pintinha et al. (2015) [29] analyzed the relationship between surface roughness and torque maintenance (21). They concluded that rougher surfaces were associated with reduced remaining torque and increased settling, while smoother or coated surfaces enhanced preload retention. The study emphasized the clinical relevance of surface finishing, advocating for polished or coated screws to maintain mechanical integrity.

Bulaqi et al. (2015) [30] performed a computational and experimental analysis to assess how surface roughness and friction affect preload . They found that increased roughness led to decreased remaining torque and preload, accompanied by a higher settling effect. Retightening improved torque retention, particularly when friction coefficients were low. The authors concluded that optimizing surface characteristics and applying retightening can substantially improve the mechanical reliability of implant–abutment joints

IV. Conclusion

Abutment screw loosening remains a multifactorial problem in implant prosthodontics. The stability of the implant–abutment complex depends on mechanical design, torque protocol, component dimension, loading dynamics, and surface characteristics. Evidence indicates that internal conical connections, timed retightening after initial torque, adequate abutment dimensions, and coated screw surfaces collectively enhance preload maintenance and joint integrity. Adopting these evidence-based strategies can significantly reduce mechanical complications and improve the long-term success of implant-supported restorations.

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