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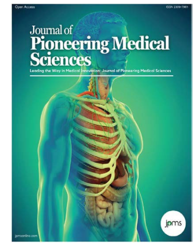

Effect of Torx and Torx+ Screw Head Geometry on Torquing Cycles to Stripping Point in Two Implant Systems: An In Vitro Study

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Abstract: **Background:** Screw head stripping remains a clinical challenge in implant dentistry because it complicates retrieval, increases treatment costs, and may compromise long-term prosthesis stability. Although various screw head geometries have been developed to improve torque transfer and reduce mechanical wear, comparative evidence on their performance under repeated tightening and loosening is limited. This study evaluated the resistance of Torx and Torx Plus (Torx+) screw designs to stripping under repeated torque cycles. **Methods:** Thirty titanium abutments with corresponding screws were divided into two groups (n = 15): Group A (Torx) and Group B (Torx+). Each fixture was embedded in acrylic resin and subjected to cycles of tightening to 35 Ncm followed by complete loosening. Baseline and follow-up surface changes were examined using scanning electron microscopy (SEM) at 10 cycles and at the point of stripping. The number of cycles until stripping was recorded, and the groups were compared using an independent samples t-test (SPSS v26, $\alpha = 0.05$). **Results:** The Torx group withstood a significantly greater number of cycles before stripping (mean 60.47±5.58) than the Torx+ group (mean 30.13±5.66) ($t = 18.76$, $p<0.001$). SEM analysis revealed irregular material displacement in Torx screws, whereas Torx+ screws showed edge rounding and smoother abrasion. **Conclusions:** Screw head geometry influences resistance to stripping. The Torx design demonstrated superior durability compared with Torx+, indicating potential advantages for clinical situations that require repeated screw manipulation. Further research is needed to confirm these findings in vivo and to assess other geometries.

Key Words: Screw Head Geometry, Dental Implants, Torx Design, Torquing Cycles, Screw Stripping

INTRODUCTION

A screw joint is a structural configuration where two components are secured together using a screw, such as the connection between an abutment and an implant. The fixation of the screw relies on the application of a controlled and reproducible rotational force, known as torque, applied by the clinician [1]. Repeated insertion and removal of prostheses increase the risk of screw head stripping, as wear occur at the interface between the screw and the screwdriver. This progressive wear reduces torque retention and may ultimately lead to stripping [2]. Additionally, excessive tightening or torque application can cause permanent deformation of the screw head, thread stripping, or even fracture [3].

Screw head stripping occurs when the upper part of the implant screw becomes damaged or distorted. This prevents proper engagement with the screwdriver during insertion or removal and can lead to further complications [4]. The success of implant-retained prostheses is heavily influenced by the mechanical integrity of the connection between the abutment and the implant fixture. Abutment screws, consisting of a head and a shaft, serve a critical role by securing the implant-abutment assembly against separation forces while maintaining retrievability for maintenance [5,6]. Screw head stripping poses a significant challenge in dental implantology, as it compromises prosthesis stability, necessitates complex retrieval procedures, increases treatment time and costs, and negatively affects patient outcomes. Highlighting and addressing this complication is essential for long-term success of implant restorations.

Various screw head geometries are employed in dental implant systems, each presenting distinct mechanical characteristics influencing their clinical performance. Commonly used geometries include Hexagonal, Torx, Torx Plus (Torx+), Phillips, and Slot designs. Hexagonal screws offer simplicity and ease of use but may have limited resistance to stripping due to fewer engagement points [5]. Phillips and Slot designs are easy to manufacture; however, they are prone to cam-out and premature stripping under high torque applications [7]. Conversely, Torx screws, characterized by a star-shaped design with six lobes, provide superior torque transfer, improved engagement stability, and a reduced risk of stripping [5-8]. Torx Plus, an advancement of the original Torx design, features wider lobes intended to further enhance torque efficiency and reduce wear [9-11]. Despite their popularity in implantology, limited evidence exists on their comparative durability under repeated tightening and loosening.

Previous studies have shown mixed results regarding screw head deformation and torque resistance, with some reporting improved torque distribution in Torx-based designs, while others observed early wear and loss of engagement. However, most investigations have been limited by small sample sizes, lack of standardized protocols, or focus on single geometries. These limitations have left uncertainty about comparative performance in clinically relevant scenarios, creating a clear knowledge gap in the literature.

Therefore, the aim of this in vitro study was to evaluate and compare the effect of Torx and Torx+ screw head geometries on the number of torquing cycles required to induce stripping. By addressing this gap, the study seeks to provide evidence-based insights that may guide implant selection and reduce mechanical complications in clinical practice.

METHODS

This in vitro study was conducted in Jeddah, Saudi Arabia, following ethical approval from the Research Ethical Committee at the Faculty of Dentistry, King Abdulaziz University (Approval No. 4493742). Two dental implant systems were tested, with their fixtures securely embedded 7 mm into separate clear acrylic bases made of epoxy resin. A total of 30 titanium abutments with their corresponding screws were divided into two groups (n = 15 per group).

Study Design

A power calculation was performed based on effect sizes from prior studies, ensuring a statistical power of 1.0 at a significance level of 0.05 to detect meaningful differences between the groups.

- **Group A:** Straumann® implant system with a Torx screw head design (Diameter: 4.1 mm; Length: 10 mm; Straumann Holding AG, Basel, Switzerland)
- **Group B:** Nobel Biocare Brånemark® system with a Torx+ screw head design (Diameter: 4.3 mm; Length: 10 mm; Nobel Biocare, Zürich, Switzerland)

All screws were sourced directly from the manufacturer to minimize variability, and only original components were used. Material properties and surface treatments were assumed consistent within each system, and this was considered in the interpretation of results.

Experimental Procedure

Each abutment underwent repeated complete cycles of insertion torque (tightening) and reverse torque (loosening) using calibrated screwdrivers and torque wrenches. The procedures adhered to manufacturer specifications and were conducted by a single investigator (B. A.), with the torque wrench recalibrated using a digital calibration device (Gedore Dremotest E, Remscheid, Germany) before the start of the experiment and after every 10 cycles to ensure accuracy. The screwdriver tips were also inspected under magnification before use and replaced if any wear was detected. To minimize bias, the experimental sequence was randomized, and imaging and statistical analyses were reviewed independently by blinded examiners.

Torque Cycles

Each torque cycle included one tightening and one loosening action, counted as a single cycle and 15- minute interval was maintained between cycles to prevent overheating or distortion. The process continued until two or more signs of screw head stripping were observed. Signs included:

- Difficulty engaging the screwdriver
- Slippage during torque application
- Inability to fully tighten or loosen the screw
- Unusual sounds (clicks or grinding)
- Loss of torque retention

Tightening and Loosining

'Tightening' was defined as the clockwise rotation of the implant screw using a calibrated mechanical torque wrench until the manufacturer's recommended torque value (35 Ncm) was achieved, indicated by the torque wrench. 'Loosening' was defined as the complete counterclockwise rotation of the screw until it fully disengaged from the abutment without resistance.

Imaging and Data Collection

Baseline Scanning Electron Microscope (SEM) images were captured using Zeiss EVO MA10 (Carl Zeiss AG, Oberkochen, Germany) at magnifications of 43x and 45x to document the initial condition of the screw heads. SEM imaging was repeated after 10 cycles at magnification of 43x, focusing on screw head deformation. Final images were captured after stripping at magnification of 45x to document progressive damage. The number of torque cycles required to reach the complete stripping point was recorded for each sample.

Statistical Analysis

Data analysis was conducted using SPSS Version 26. After confirming data normality, an Independent Samples t-test was performed to compare the means of the two groups, with the significance level of $p = 0.05$. Levene's test was applied to confirm homogeneity of variances before performing the t-test. The methodology and statistical procedures were reviewed by an independent statistician.

RESULTS

The number of torquing cycles required for each sample until screw head stripping occurred is presented in Table 1.

Group A (Torx) had a mean of 60.47 cycles (SD = 4.99), while Group B (Nobel Biocare) had a mean of 30.13 cycles (SD = 4.10). Descriptive statistics for both groups are shown in Table 2.

A normality test using the Kolmogorov-Smirnov and Shapiro-Wilk tests confirmed that the data followed a normal distribution ($p > 0.05$). An independent samples t-test showed a statistically significant difference between the two groups in the number of torquing cycles required to induce stripping ($t = 14.78$, $p<0.001$), as detailed in Table 3 indicating significantly greater durability of the Torx design under the standardized 35 Ncm torque protocol.

Table 1: Raw Data Showing the Number of Torquing Cycles Required to Induce Stripping in Both Groups

Sample No.	Group A (Torx)	Group B (Torx +)
1	72	21
2	55	43
3	65	33
4	56	24
5	71	29
6	54	30
7	57	25
8	64	31
9	60	42
10	61	22
11	58	32
12	61	32
13	63	28
14	57	31
15	53	29

Table 2: Descriptive Statistics for both Groups

Group	Mean Cycles	Standard Deviation	Standard Error Mean	95% Confidence Interval
Group A (Torx)	60.47	5.58	1.44	57.66 - 63.28
Group B (Torx +)	30.13	5.66	1.46	27.27 - 33.00

Table 3: Independent Sample t-test Results Comparing the Number of Torquing Cycles between Torx and Torx+ Groups

Test	Levene's Test for Equality of Variances	t-Statistic	df	p-Value	Mean Difference	Std. Error Difference	95% Confidence Interval
Equal variances assumed	F = 0.024, p = 0.878	18.76	28	< 0.001	30.34	1.62	27.04 to 33.63
Equal variances not assumed	—	18.76	27.97	< 0.001	30.34	1.62	27.04 to 33.63

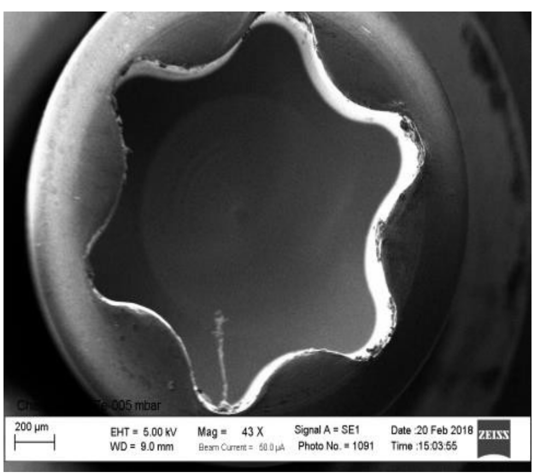

Figure 1: Baseline Sem Image showing Screw Head Conditions for Torx Design before the Procedure. Image Captured and Processed with Zeiss Smartsem Version 6.04 (Carl Zeiss Ag, Oberkochen

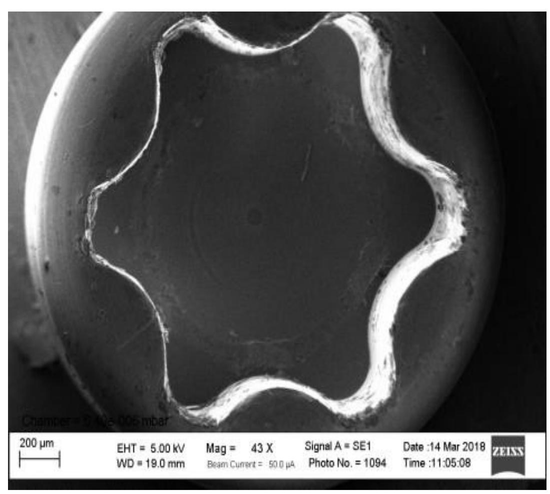

Figure 2: SEM Image after 10 Cycles (Torx Design). Image Captured and Processed with Zeiss Smartsem Version 6.04 (Carl Zeiss AG, Oberkochen, Germany)

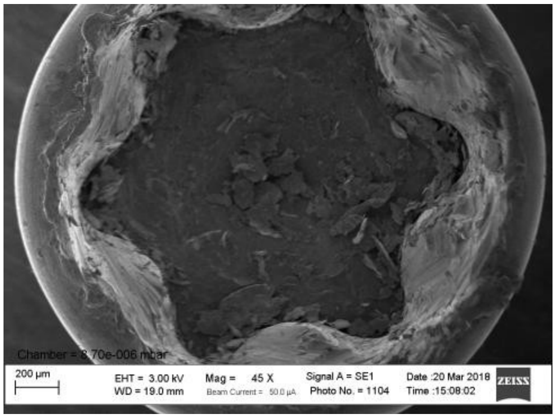

Figure 3: SEM Image after Complete Stripping (Torx Design). Image Captured and Processed with Zeiss Smartsem Version 6.04 (Carl Zeiss AG, Oberkochen, Germany)

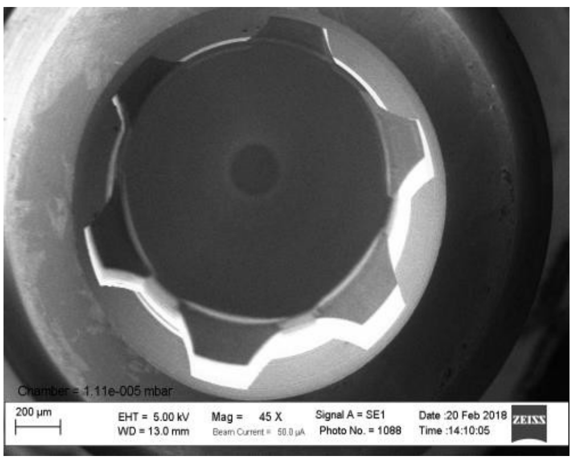

Figure 4: Baseline SEM Image Showing Screw Head Conditions for Torx+ Design before the Procedure Image Captured and Processed with Zeiss SmartSEM Version 6.04 (Carl Zeiss AG, Oberkochen, Germany)

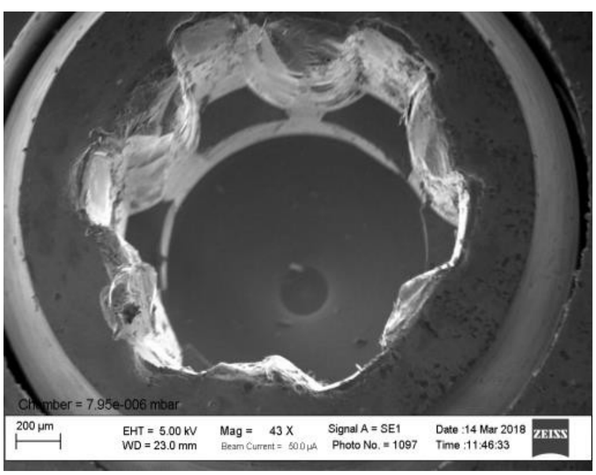

Figure 5: SEM Image after 10 Cycles (Torx+ Design). Image Captured and Processed with Zeiss Smartsem Version 6.04 (Carl Zeiss AG, Oberkochen, Germany)

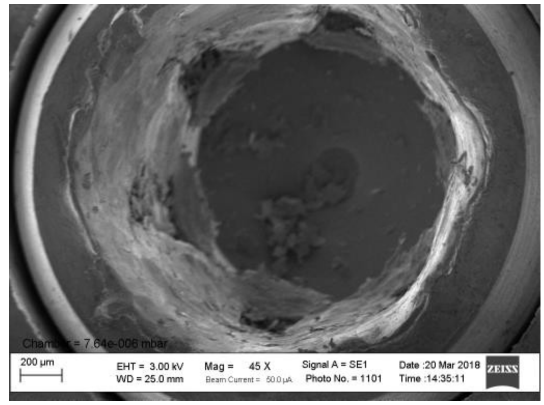

Figure 6: SEM Image after Complete Stripping (Torx+ Design). Image Captured and Processed with Zeiss Smartsem Version 6.04 (Carl Zeiss AG, Oberkochen, Germany)

Baseline SEM images showing screw head conditions for Group A (Torx) and Group B (Torx +) (Figures 1 and 4)reveal intact screw head surfaces for both groups. After 10 cycles, minor surface deformations appear (Figures 2 and 5) without significant stripping. At the point of stripping, Group A (Figure 3) displays irregular wear patterns and material displacement, while Group B (Figure 6) shows pronounced edge rounding and smoother abrasion, indicating differing wear characteristics between the two designs.

DISCUSSION

This study provides novel insights into the influence of screw head geometry on the mechanical performance of dental implant screws under repetitive torquing conditions. While similar studies have evaluated screw head geometries in other engineering applications, the data specific to dental implantology remain limited. This experiment compares the performance of Torx and Torx+ designs under clinically relevant torquing condition. Screw head stripping, a critical issue in implant prosthodontics, is often attributed to factors such as excessive torque application, improper engagement between the driver and screw head, suboptimal tools, or the use of low-quality screws [3,4].

The findings of this study demonstrate that the Torx design significantly outperforms the Torx+ design in resisting stripping, highlighting the effect of geometry on enhancing screw durability and ensuring long-term clinical success. These results are consistent with prior reports on the torque efficiency of Torx-based designs, yet they contrast with findings suggesting that Torx Plus offers improved wear resistance, highlighting variability depending on experimental conditions. This might be due to some differences between the two designs. In the case of the Torx design, its star-shaped geometry with six points of contact facilitates greater torque transfer, improved mechanical stability, and enhanced stress distribution, making it suitable for a wide range of applications [7,8].

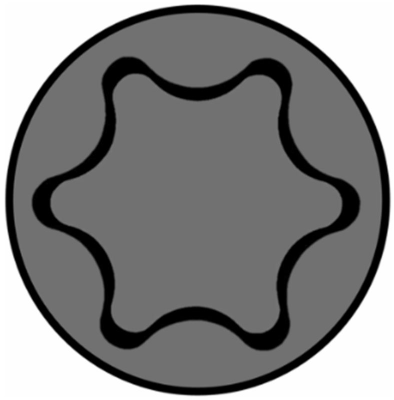

Figure 7: Schematic Representation of the Screw Head Geometry of Torx Design. *Lobe*: The Protruding Parts of the Screw Head that Engage with the Driver. *Lobe Arc*: The Curved Edge of a Single Lobe, Indicating its Shape and Profile. *Driving Angle*: The Angle between the Screwing Direction and the Side of the Lobe. Created Using Adobe Illustrator CC 2023 (Adobe Inc., San Jose, CA, USA)

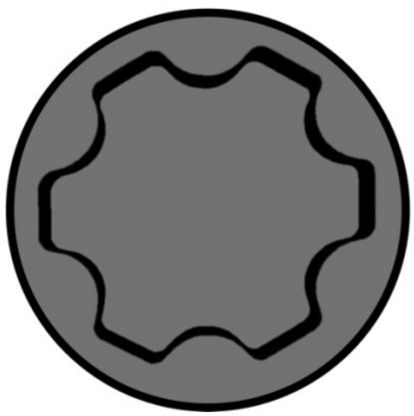

Figure 8: Schematic Representation of the Screw Head Geometry of Torx Plus Design. *Lobe*: The Protruding Parts of the Screw Head that Engage with the Driver. *Lobe Arc*: The Curved Edge of a Single Lobe, Indicating its Shape And Profile. *Driving Angle*: The Angle between the Screwing Direction and the Side of the Lobe. Created Using Adobe Illustrator CC 2023 (Adobe Inc., San Jose, CA, USA). These Findings Confirm the Study Hypothesis that Screw Head Geometry Influences Resistance to Stripping, with Torx Screws Demonstrating Superior Performance Compared with Torx+

The driving angle, defined as the angle formed between the screwing direction and the side of the lobes, is a critical factor in performance. Low driving angles can generate excessive radial forces, which act perpendicular to the turning force and contribute minimally to effective screwing (Figure 7). While this feature has been extensively described in the literature, here it is highlighted as one of the main factors explaining the observed differences between groups. Excessively low driving angles also pose risks of socket bursting and driver crushing, as the resulting extreme radial forces can round off the corners of both the socket and the driver, ultimately causing slippage. Conversely, high driving angles improve torque transfer efficiency while minimizing detrimental radial forces. This feature allows the Torx design to maintain a smaller head while delivering the required torque, a distinct advantage in applications where space is limited [7,8].

The Torx Plus, introduced as an enhancement of the original Torx, features wider and flatter lobes, increasing its ability to transfer torque efficiently and reducing wear and slippage (Figure 8). The Torx Plus design is particularly beneficial in high-performance applications where frequent tightening and loosening occur, as it offers greater resistance to camp-out and prolongs the life of both the screw and tool. The improved geometry of Torx Plus results in enhanced durability, reduced tool wear, and a longer lifespan for fasteners in demanding applications, such as automotive and medical device manufacturing [9-11]. However, despite these theoretical advantages, Torx Plus stripped significantly earlier than Torx in the present study, a finding that diverges from its expected performance.

This discrepancy may be attributed to material properties, variations in manufacturing tolerances, or differences in the driver-screw engagement. Additionally, the broader lobes and flatter geometry of the Torx Plus screws, while designed to improve torque efficiency, may have resulted in higher radial forces and localized stress, increasing the likelihood of stripping under the experimental conditions.

Although Torx Plus screws are designed with enhanced geometry—featuring wider, flatter lobes to improve torque transfer and reduce wear—their earlier stripping observed in this study may be attributed to several factors. These include higher radial forces at lobe edges, shallower driver engagement leading to cam-out, and potential manufacturing variations. Streamlining these explanations, the combined effect appears to accelerate material fatigue and reduce torque resistance compared with the more compact Torx design.

Further investigations into the material composition, manufacturing precision, and application-specific limitations of the Torx Plus design are warranted to better understand these findings. These findings align with previous research highlighting the mechanical advantages of Torx geometries in distributing torque forces more evenly across the screw head. The enhanced resistance observed in the Torx design may be attributed to its broader surface contact and reduced susceptibility to wear. In contrast, the Torx+ design, despite offering an improved engagement profile, appears more prone to edge rounding and smoother abrasion under repeated cycles, as evidenced by the SEM images. Overall, the present findings support the hypothesis that screw head geometry significantly affects stripping resistance under repeated torque cycles.

Other factors must also be considered to minimize the risk of screw head stripping in clinical practice. It is essential for clinicians to follow the manufacturer's instructions and apply the correct torque during the insertion and removal of abutment screws to prevent damage to the screw head. Selecting abutment screws with a conical head design and appropriately dimensioned screwdriver slots can further reduce the risk of stripping by ensuring proper engagement and torque transfer. Moreover, the optimal torque value is recommended to be approximately 75% of the torque required to induce screw failure, as excessive tightening significantly increases the likelihood of screw head deformation [1]. The reverse torque required to remove a screw is generally less than the initial insertion torque, which highlights the importance of accurate torque application during the initial placement [12]. Consistency in torque application is crucial, and clinicians should utilize mechanical torque instruments rather than hand drivers, as mechanical instruments ensure precise torque values in accordance with implant manufacturer recommendation [13]. As an in vitro study, the findings may not fully replicate the complex forces and conditions encountered in vivo. Therefore, caution is needed when interpreting these results and further validation in a clinical setting is essential to confirm the findings.

Additionally, the sample size, while statistically powered, may limit the generalizability of the results. Other limitations include the use of only two screw geometries and the lack of assessment of material composition or manufacturing tolerances, which may also influence outcomes.

Clinically, the superior resistance of the Torx design suggests potential for reducing mechanical complications and extending prosthesis longevity, particularly in cases requiring frequent screw manipulation. Future research should expand comparisons to include other geometries and in vivo testing to confirm these findings.

CONCLUSIONS

In conclusion, screw head geometry significantly impacts the resistance to stripping. The Torx design outperformed the Torx+ design in this study, demonstrating superior durability during repetitive torquing cycles. These findings suggest that selecting appropriate screw geometries may help reduce mechanical complications and improve long-term stability in implant prosthodontics. However, as this was an in vitro study conducted under controlled conditions, the results should be interpreted with caution, and further clinical and comparative studies involving other geometries are warranted.

Declaration of Figures Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part

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