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Original Article

Influence of Re-Torque Timing on Removal Torque in Implant-Abutment Connections: An In Vitro Study

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Abstract

Background and Aim: This study aims to evaluate the influence of various retorque timepoints on removal torque amounts in two types of implant-abutment connections.
Methods: In this experimental study, 32 Tixos cylindrical implants were used, divided into four groups based on retorque timepoints using simple randomization: 1- internal hex connection with retorque at 10minutes, 2- internal hex connection with retorque at 10minutes and one month later, 3- Morse taper connection with retorque at 10minutes, and 4- Morse taper connection with retorque at 10minutes and one month later. Abutment screws were tightened using a digital torque meter, followed by retightening after 10 minutes. Subsequent retorquing for Groups 2 and 4 occurred after 85,000 loading cycles. Removal torque measurements were recorded using a digital torque meter. Data was analyzed using SPSS 29 software and the independent samples T-test with Bonferroni correction for multiple comparisons.
Results: The average removal torque in Group1(19.03 ± 0.83) was significantly lower than Group2(21.20 ± 0.98) (p-value < 0.001). However, the average removal torque of Group3(21.60 ± 0.87) and Group4(21.90 ± 1.02) was not statistically significant(p-value=0.186). Regarding the difference between using these two connections, Group 1 had a significantly lower mean removal torque compared to Group 3 (p-value < 0.001), while the difference between Group 2 and Group 4 was not statistically significant (p-value = 0.539).
Conclusion: Current study suggests that abutments with Morse taper connections outperform internal hex connections when retorquing is only applied after 10minutes. Retorquing abutments with internal hex connections one month after cyclic loadings also reduces the settling effect and decreases screw loosening.
Key Words: Abutment Screw Loosening; Dental Implant-Abutment Connection; Dental Implant-Abutment Design; Morse Taper Connection; Retightening Torque

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Introduction

The design of the implant-abutment connections influences the mechanical and biological properties of implants. One of the most common problems associated with implant-supported restorations, is the lack of stability in the initial torque of the abutment screw, with a prevalence ranging from 2% to 40%. Loose and unstable prosthetic screws can lead to severe complications, including the formation of granulation tissue between the abutment and the implant, which results in soft tissue infection and the potential loosening or breakage of abutment screws (1-5).
Mechanical factors such as the applied torque force

and the frequency of cyclic loading have an impact on screw loosening. Various techniques have been suggested in order to minimize the risk of screw loosening, such as ensuring correct preload in the screws, using a narrow occlusal table, establishing central occlusal contact, flattening cusp slopes, and reducing abutment length (6-9). It has been reported that the most effective method to reduce screw loosening is to increase the preload of the screw and enhance the clamping force at the joint (10). However, a significant preload loss, typically around 17%–29%, can occur due to the settling effects. This happens when wear between the screw and implant surface brings them closer together, reducing the clamping force and making the screw more prone to loosening. The issue of settling effect can be addressed through a procedure called retorque, where abutment screws are tightened again after the initial torque application. This retorque practice has increased removal torque by 13.7%–32%(11-13) and diminish torque force loss by approximately 50% compared to applying torque just once (11).

Mastication simulation helps researchers understand how materials handle chewing forces. Cyclic loading tests mimic clinical conditions for evaluation (14). The instructions for different implant systems lack specific details regarding tightening methods (11). While most studies suggest a 10-minute timepoint for retorquing, none have investigated longer retorque interval's effect on the clinical performance of implant restorations (15, 16). The instructions for various implant systems lack details about specific tightening methods, such as the interval between successive tightening instances, and there is still no consensus on this matter (11). The current study aimed to explore how different retorquing timepoints affect the removal torque amounts in abutments with Morse taper and internal hex connection.

Background

This experimental, in vitro study was conducted at Tehran Islamic Azad University dental branch from March to July 2023. The removal torque is a quantitative variable, and the study is conducted in vitro. Based on previous research, the rate of change in removal torque is minimal; therefore, 8 implants are included in each group (17-20).

A total of 32 samples of Tixos cylindrical implants (Tixos cylindrical, Milan, Italy) were utilized, comprising 16 Tixos cylindrical MC fixtures with Morse taper abutments, 16 Tixos cylindrical internal hex fixtures with internal hex abutments. These samples were divided into four groups based on retorque time points: Group 1: Internal hex connection/ retorque at 10 minutes, Group 2: Internal hex connection/ retorque at 10 minutes and one month after cyclic loads, Group 3: Morse taper connection/ retorque at 10 minutes, Group 4: Morse taper connection/ retorque at 10 minutes and one month after cyclic loads.

The implants used in this study had dimensions of 10mm*4 mm. Direct abutments with a diameter of 4 mm and a collar height of 2 mm were employed. The samples were initially mounted within acrylic resin molds with a circular cross-section of 22 mm in diameter and height filled with self-polymerizing acrylic resin (Rapid Repair, Meliodent, HeraeusKulzer GmbH, Germany). According to the factory instructions, an appropriate ratio of powder to liquid was used for all samples. To mount the fixtures within the acrylic mold in a perfectly vertical position while ensuring that the fixture surface was 2 mm above the acrylic surface, a surveyor device (J.M. Ney Co., Bloomfield, CT, USA) was utilized. The samples were allocated to the four experimental groups using simple randomization. Specifically, a computer-generated random number sequence was used to assign the coded samples (1 to 32) to the four groups. The abutments were secured onto the samples, and the abutment screws were tightened using a digital torque meter (Lutron Electronic Enterprise CO, Taiwan) with a force of 25 Ncm following the factory instructions. The abutment screws were retightened using the same digital torque meter after 10 minutes. Groups 2 and 4 were re-tightened with the same force after 85,000 loading cycles equivalent to one month of clinical performance(21). Afterwards, cyclic loading with an amplitude of N150 at a frequency of 15 hertz for a total of 1,000,000 cycles (equivalent to 12 months of chewing force under clinical conditions) was applied to the flat surface of each specimen (16). The removal torque of each sample was measured by a digital torque meter, recording the force required to loosen the abutment screw. Torque loss was calculated using the following formula: Torque Loss (%) = [(Initial Torque Value –Removal Torque value)

/ Initial Torque Value] × 100. To minimize potential measurement bias, the examiner responsible for recording and compiling the removal torque values was blinded to the group coding.

The collected data were entered into SPSS statistical software (version 20) for analysis. Based on the specific objectives and hypotheses of the study, descriptive statistics including the mean and standard deviation (SD) were used to summarize the data.

The collected data were entered into SPSS statistical software (version 20) for analysis. Prior to using parametric methods, the assumptions of normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) were checked and met. Based on the specific objectives and hypotheses of the study, descriptive statistics including the mean and standard deviation (SD) were used to summarize the data. Initially, the removal torque values were assessed using a Two-Way Analysis of Variance (ANOVA). However, since the interaction effect between Connection Type and Retorque Timing proved to be statistically significant, the standard procedure required shifting focus to the Simple Main Effects. Consequently, the data were analyzed separately using the independent samples T-test to examine the differences in removal torque amounts between the various re-torque time points. To control the Type I error rate resulting from multiple comparisons, the Bonferroni correction was applied to the significance level.

Results

The data of removal torque amounts is presented in Table 1. The highest mean removal torque was observed in Group 4 (21.90 ± 1.02 Ncm). Conversely, the lowest mean removal torque amount was recorded in Group 1 (19.03 ± 0.83 Ncm).

Regarding different retorque timepoints, Group 1 (Internal hex connection - 10 minutes) had a significantly lower mean removal torque than Group2 (Internal hex connection - 10 minutes and one month) (*P*-value =0.000). However, the difference between Group3 (Morse taper connection - 10 minutes) versus Group4 (Morse taper connection - 10 minutes and one month) was not statistically significant, with *P*-value of 0.186.

Concerning the use of different connections, the removal torque in Group 1 was significantly lower (*P*-value 0.000) compared to Group 3, whereas the difference between Group 2 and Group 4 was not statistically significant (*P*-value 0.539) (figure 1). Torque loss percentages in abutments with morse taper and internal hex connections are shown in figure 2.

Discussion

The current study aimed to determine the optimal retorquing time point by investigating its influence on removal torque in two distinct implant-abutment connection designs. The most significant finding of this study is the differential impact of the one-month retorque intervention on the two connection types. We observed a statistically significant increase in the mean removal torque for the Internal Hex connection when retorquing was performed at the one-month time point. This result suggests that the extended period and cyclic loading allow for maximum screw-joint settling in the Internal Hex system, which is then effectively managed by the delayed retorque.

A systematic review revealed that, in most cases, conical implant abutment connection systems demonstrate lesser amounts of torque loss compared to external and internal connection systems (22).

Many studies have indicated that retorquing after 10 minutes can effectively decrease preload loss. The study by Siamos et al. and Kanyarin Benjaboonyazit et al. showed a significant improvement in the removal torque amount of internal hex connections when a retightening intervention is applied 10 minutes after the initial torque (15, 16). Sun et al. reported another method in which after the initial torque, loosening of the screw and immediate retorquing is applied which has similar results to retorquing after 10 minutes (11); but they did not investigate the effect of longer intervals of retorquing like the present study.

In contrast to the findings of the present study, Varvara et al. found that retightening at 2 minutes after the initial torque significantly reduces preload loss even better than longer retorque intervals of 5,10 and 30 minutes (23). This might be due to the

Connection design		Group	Number	Mean and SD	Minimum	Maximum	*P*-value		
Internal hex	10min	1	8	19.03±0.83	17.8	20.2	0.000	Group 1	0.000
	10min and 1month	2	8	21.20 ±0.98	20.3	23.1		Group 3	
Morse taper	10min	3	8	21.60±0.87	19.8	22.7	0.186	Group 2	0.539
	10min and 1month	4	8	21.90±1.02	20.5	23.1		Group 4	

Table 1. The Effect of Different Retorque Times on Removal Torque in Internal Hex and Morse Taper Connections

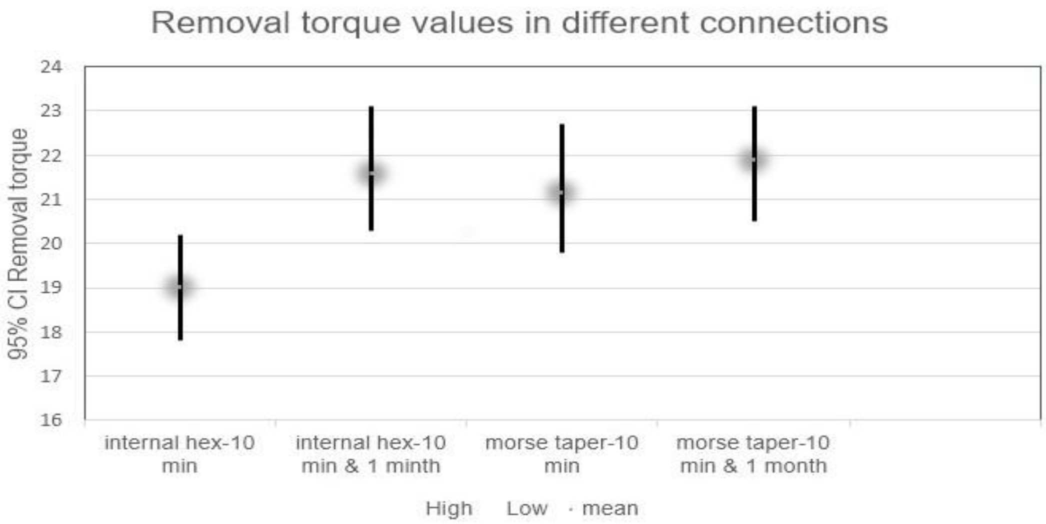

Figure 1. The effect of different retorque timepoints and connection on removal torque values

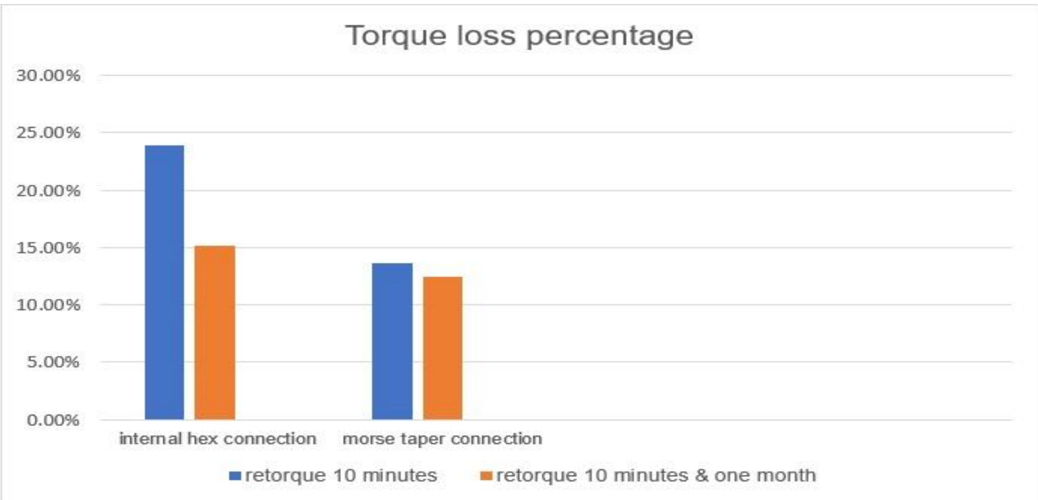

Figure 2. Torque loss percentage in Internal hex and Morse taper connections

fact that they did not subject the implants to any cyclic loading and simply measured the removal torque 30 minutes after the torquing process.

The present study results were in contrast with those of Bacchi et al., which showed that the tightening technique does not significantly affect the removal torque of abutments with external hex connection (24). The difference could be attributed to investigating solely retorquing after 10 minutes or applying torque force for 20 seconds. The other cause to the contrast can be due to experimenting abutments with external hex connection while present study investigated morse taper and internal connections that are much more common nowadays because of their superior esthetic characteristics and lesser mechanical problems such as screw loosening (25, 26).

Norton presented that across all clinically relevant torque levels, in both dry conditions and when components were submerged in artificial saliva at 37°C, the loosening torque consistently ranged from 80% to 90% of the tightening torque. This demonstrates the absence of cold welding (27). Among the four groups in our study, only group 1 demonstrated a torque loss of less than 80%. The remaining groups exhibited torque losses exceeding 80%. This indicates that the statistically significant difference observed in this study is also clinically meaningful.

The present setting of the investigation only relied on an in vitro environment with the absence of the gums, oral mucosa etc. which may only partially replicate the complex conditions present in actual clinical settings. Future studies should explore other intervals for the retorque intervention across different cycles to enhance implant-supported restoration's long-term performance. The findings of this in vitro study should be interpreted considering several limitations. While our sample size (n=8 per group) was determined based on similar methodology in previous mechanical studies, we acknowledge that it limits the statistical power and increases the risk of a Type II error. Also, this study relied exclusively on one specific implant brand (Tixos), which limits the generalizability of our findings due to potential variations in manufacturing tolerances across systems. While the T-test with Bonferroni correction was chosen for its direct relevance to our a priori hypotheses, we acknowledge that this approach did not formally analyze the potential interaction effect between connection type and retorque timing. We recommend that future research focusing on the interaction between these two factors employ a more comprehensive analysis, such as Two-Way ANOVA, especially in studies with larger sample sizes. Additionally, investigating the impact of other variables, such as screw design, material, compatibility, and abutment diameter, in conjunction with retorque intervention after one month of clinical performance is recommended.

Conclusion

It was noted that retorquing 1 month after clinical function can enhance performance and may reduce the settling effect, potentially decreasing screw loosening in internal hex connections. However, retorquing solely after 10 minutes is insufficient to maintain preload and eliminate the settling effect phenomenon. Conversely, in Morse taper connections, the difference between performing and not performing retorque one month after clinical performance is insignificant.

Declarations

Ethical Approval and Consent to Participate

This study is an in vitro laboratory investigation that did not involve human participants, human tissue, animal subjects, or any clinical procedures. All implant-abutment components and test models used in this study were commercially available, manufactured products. Therefore, ethical approval and informed consent were not required for this research.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors have reviewed and approved the final manuscript and confirm that there are no conflicts of interest associated with this publication.

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Authors' Contributions
This work was carried out in collaboration among all authors. Ezzatollah Jalalian (EJ) and Mohammad Shariati (MS) were responsible for the study concept, experimental design, and overall supervision of the research process. Ghazal Nosrati (GN) and Zeinab Akbarzadeh Fathabadi (ZA) contributed to the investigation, literature search, data acquisition, and writing of the original manuscript draft. Parham Elahinia (PE) performed the formal statistical analysis, validated the data, and contributed to manuscript editing, review, and visualization. Shervin Shafiei (SS) participated in data interpretation, analysis validation, and critical revision of the manuscript for important intellectual content.
All authors had full access to the study data, reviewed and approved the final version of the manuscript, and agree to be personally accountable for their own contributions and for ensuring that questions regarding the accuracy or integrity of any part of the work are appropriately resolved. The corresponding author, Dr. Ghazal Nosrati (GN), confirms that all listed authors meet the ICMJE criteria for authorship and that no eligible authors have been omitted.

Declaration of Generative Artificial Intelligence (AI) Utilization
During the preparation of this work, the authors used ChatGPT (OpenAI) to assist with grammar checking, language refinement, and improving the clarity and readability of the manuscript. After using this tool, the authors carefully reviewed, verified, and edited the content as necessary and take full responsibility for the accuracy, integrity, and originality of the published work. No AI tools were used for data analysis, interpretation, or any aspect of the research methodology, which was conducted entirely by the authors using conventional laboratory and statistical methods.

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