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Original Research

Effects of different angles of abutment screw channel on removal torque value of ball torx screws

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Aim: This study investigates the impact of various tightening protocols on torque requirements in screw-retained crowns, focusing on the Angulated Screw Channel (ASC) system. The ASC alters the screw channel angle in the crown while aligning the abutment with the implant, potentially enhancing function and aesthetics in cases of improper implant positioning. **Methods:** The investigation involved three sample groups: DIO abutment with 0-degree screw access and regular screw (D0), Ti-base angled screw channel abutment with 0-degree access and ball torx screw (A0), and Ti-base with 20-degree access and ball torx screw (A20). Each group was subdivided into four protocol categories, using nine screws each. Screws were initially hand-tightened, then subjected to the respective tightening protocols, with torque measurements taken using a calibrated Digital Torque Meter. **Results:** Significant statistical differences in torque requirements were observed between the D0 group and both the A0 and A20 groups. However, the torque reduction percentage did not vary significantly among the different tightening protocols or between the 0- and 20-degree angles in the ASC system. The results indicate notable distinctions in torque needs between standard and angled screw channel systems. The lack of significant variance in tightening protocols and angles within the ASC system suggests consistency in torque requirements, regardless of these factors. **Conclusions:** While the ASC system demonstrates a significant difference in torque requirements compared to the traditional system, the angle of the screw channel and the tightening protocol do not substantially affect torque reduction in the ASC system.

Keywords: Dental abutments. Dental implants. Esthetics, dental. Crowns.. Torque.

Introduction

Endosteal dental implants are a suitable option for replacing missing teeth[1]. Due to the high success of osseointegrated dental implants, more patients can enjoy the benefits of fixed dental prostheses compared to removable ones[2]. Patients expect longevity, functionality, and esthetics from implant-supported restorations[3]. Achieving the desired aesthetic for implant-related restorations largely depends on patient choice, the type and volume of the surrounding soft and hard tissues, and the implant's position[4].

In cases where the implant position is unsuitable or has an undesirable angle, a screw-retained crown might be contraindicated, as the screw access channel might compromise function or esthetic[4]. A cemented crown can eliminate these complications. However, many clinicians prefer screw-retained prostheses as they can prevent the presence of residual cement and reduce risks to the soft tissue[5].

Past solutions for solving this issue and placing a screw-retained crown include augmenting the implant placement site, using lateral screws, and utilizing angulated prosthetic platforms[6,7]. A newer therapeutic solution is the angled screw channel (ASC). This concept changes the angle of the screw access channel in the crown while keeping the abutment angle aligned with the implant. This system can be used with titanium-based abutments and is designed using computer-aided design and computer-aided manufacturing (CAD-CAM) technologies[8]. With the help of these abutments, one can avoid having the access channel exit from the facial side of the crown[4,9]. Furthermore, one can position the screw access hole more mesially at the posterior of the mouth. Studies examining the difference between screws used in the angled screw channel system, which are subjected to off-axis torque, and those with direct screw access, are scattered and few.

Among technical complications, abutment screw loosening is one of the most common problems. It leads to an increase in micromotion and the creation of a micro-gap at the implant-abutment junction, intensifying microleakage, which ultimately results in biological complications[10-12]. Tightening the screw generates a clamping force between the implant fixture and the abutment, known as preload, which draws these two parts together. When the torque force is below the recommended value, insufficient clamping force can lead to screw loosening[1].

Although previous studies have reported on various torque application methods and their effects on reducing embedment relaxation effects, research on the behavior of hexalobular screws with different designs (used in ASC systems) when torque is applied off-axis, and its impact on removal torque compared to direct screw access systems, is limited. Therefore, in this study, we examined the differences in removal torque of Ball Torx screws used in the ARUM company's angled screw channel system compared to hexagonal screws used in the DIO company's direct screw access system.

Our study evaluated and compared the amount of reverse torque value required to remove ball Torx screws. Then, the reverse torque value needed to remove ball torx screws with 0 and 20 screw access channel angle degrees was compared. Additionally, the reverse torque needed to remove ball torx screws was compared with regular screws with a screw access channel angle of 0 degrees.

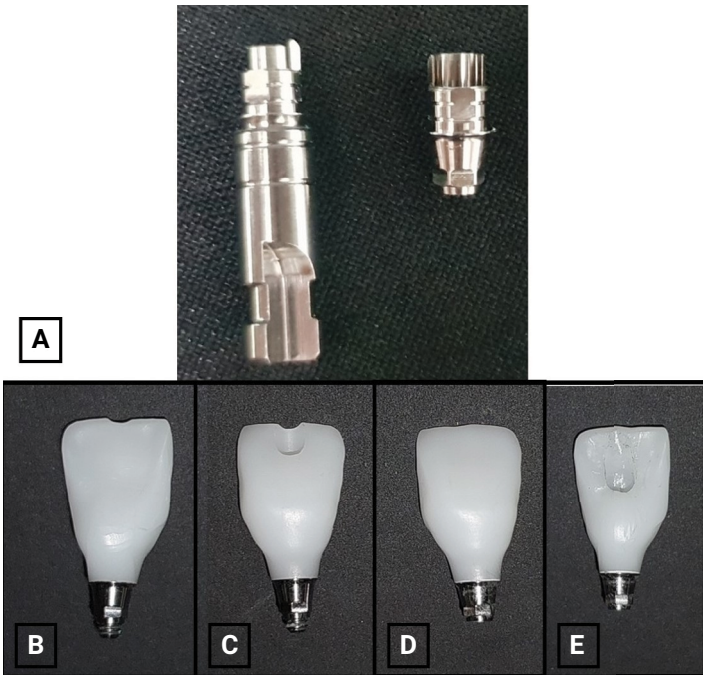
Material and Methods

This in vitro study was conducted in 2023 at the Faculty of Dentistry, Tabriz University of Medical Sciences, Iran. The study protocol was approved by the ethics committee of the university (Institutional Review Board: IR.TBZMED.VCR.REC.1400.54).

In this study, samples were categorized into three groups. In each group, the samples were divided into four subgroups with different tightening protocols and nine screws were used for each subgroups tightening protocol: Group 1 (D0) consisted of a DIO implant fixture, a DIO abutment with a 0-degree screw access channel angle with the implant, and a screw from the DIO company; Group 2 (A0) included a DIO implant fixture, a Ti-base angled screw channel abutment from the Arum dental company with a 0-degree screw access channel angle with the implant, and a screw from the Arum dental company; Group 3 (A20) was comprised of a DIO implant fixture, a Ti-base angled screw channel abutment from the Arum dental company with a 20-degree screw access channel angle with the implant, and a screw from the Arum dental company.

Custom angled screw channel abutment and crown fabrication

On the Ti-base abutment, two upper right central crowns with an anatomical contour were specifically designed channels. In their design, screw access channels with angles of 0 and 20 degrees were applied (Figure 1).



A: Ti Base Abutment(right) - Ti Base Abutment with fixture analog(lift)
B: labial view of right central crowns with anatomical contour and screw access channels 0 degrees
C: palatal view of right central crowns with anatomical contour and screw access channels 0 degrees
D: labial view of right central crowns with anatomical contour and screw access channels 20 degrees
E: palatal view of right central crowns with anatomical contour and screw access channels 20 degrees

Figure 1. Ti Base Abutment and the crown fabricated on it.

Fixture holder jig fabrication

The mounting of the fixtures was carried out using a dental surveyor. Three UFII Int. Submerged system implant fixtures from DIO Company-Korea were mounted within a self-polymerizing methyl methacrylate resin block (Alike, GC America).

To ensure the stability of the resin block and the Digital Torque Meter during the experiment, a custom-made device was used. The abutments are movable in the vertical direction. The custom-made device was similar to the one described in Choi's study[13], but with slight modifications. This apparatus consisted of a Digital Torque Meter (TQ8800, Lutron, Taiwan), a Ball Torx screwdriver, and a DIO screwdriver, accompanied by the fixture holding jig (Figure 2).

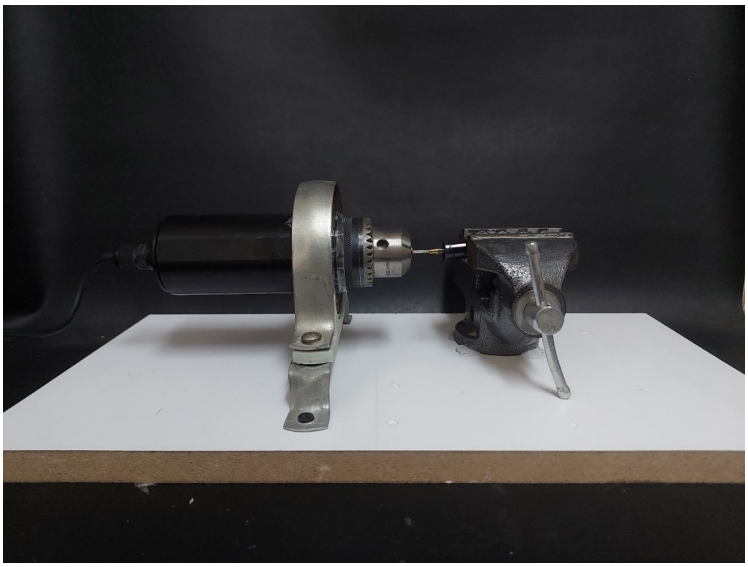


Figure 2. Custom-made device for measuring torque and reverse torque.

The prefabricated abutment, as well as the Ti-base angled screw channel abutments, were mounted onto the implant fixtures. Subsequently, the implant abutment screws were inserted. The screws were then hand-tightened using both the DIO screwdriver and the ball screwdriver.

Tightening protocols

In Group 1 (D0) for each 4 subgroups tightening protocol (T1 to T4), screw torque 30NCm (according to recommended DIO company) was applied.

In Group 2 (A0) and Group 3 (A20) for each 4 subgroups tightening protocol (T1 to T4), screw torque 20NCm (according to recommended ARUM company) was applied.

Before starting any screw-tightening procedure, the Digital Torque Meter was calibrated. In this study, for tightening protocol, inspiration was taken from the study by Alnasser et al. in 2020, which is briefly explained below[14]:

T1: Screws, using a screwdriver and the Digital Torque Meter and based on the manufacturer's recommended torque, were torqued once and the removal torque was immediately recorded.

T2: Screws, using a screwdriver and the Digital Torque Meter and based on the manufacturer's recommended torque, underwent two cycles of torque - reverse torque, and immediately afterward, the removal torque was recorded.

T3: Screws, using a screwdriver and the Digital Torque Meter and following the manufacturer's recommended torque, went through three cycles of torque - reverse torque, and immediately, the removal torque was recorded.

T4: Screws, using a screwdriver and the Digital Torque Meter and following the manufacturer's recommended torque, were torqued and then retorqued after 10 minutes, and immediately, the removal torque was recorded.

Measurement of removal torque

To measure the removal torque, the maximum torque values required for removal were measured using the Digital Torque Meter. All measurements were done by one clinician. The percentage difference in RTV was calculated based on the study by Swamidass et al.[15]:

$$\textit{Percentage difference} = \frac{\text{insertion torque} - \text{removal torque}}{\text{insertion torque}} \times 100$$

Statistical analyses were conducted using GraphPad Prism software, version 9.5.1, for Windows. Throughout the study, a significance level was set at $p<0.05$. The comparison of removal torque values among the three primary groups and their respective four tightening protocol subgroups was achieved through a two-way analysis of variance (ANOVA), followed by post-hoc evaluations using the Tukey HSD test at a significance level of $\alpha = 0.05$.

Results

The measured average removal torque values in the group D0 and torque protocols T1, T2, T3, and T4 were 26.56, 26.00, 26.44, and 26.89, respectively. In group A0, the torque protocol values for T1, T2, T3, and T4 were 14.44, 16.56, 14.67, and 14.78, respectively. The values for the group A20 were 16.22 for T1, 13.78 for T2, 14.89 for T3, and 15.33 for T4 (Figure 3) (Table 1).

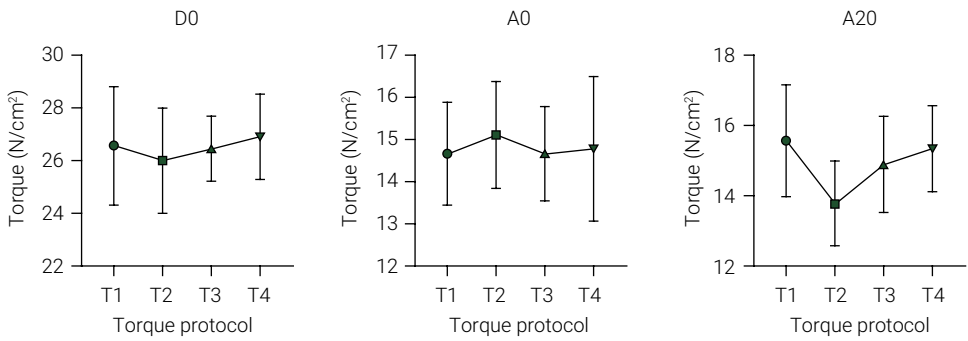


Figure 3. Average torque values measured in the three groups following four tightening protocols.

Table 1. Mean and SD of removal torque values in the 3 groups

	D0		A0		A20	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
T1	26.56	2.24	14.44	1.33	16.22	2.17
T2	26	2	16.56	1.59	13.78	1.2
T3	26.44	1.24	14.67	1.12	14.89	1.36
T4	26.89	1.62	14.78	1.72	15.33	1.22

To eliminate the effect of different initial torque values in the groups, the average percentage reduction in torque was measured. Accordingly, in the group D0, it was 11.48 for torque protocol T1, 13.33 for T2, 11.85 for T3, and 10.37 for T4. In group A0, they were 26.67, 24.44, 26.67, and 26.11 for T1, T2, T3, and T4 protocols, respectively. In group A20, they were 22.22, 31.11, 25.56, and 23.33 for T1, T2, T3, and T4 protocols, respectively (Figure 4).

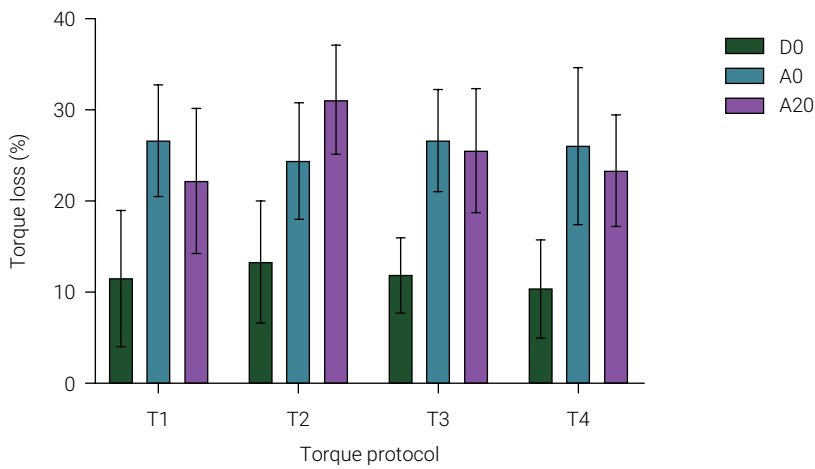


Figure 4. Average percentage decrease torque values measured in the three groups following four tightening protocols

There were significant differences between the groups D0 and A0, as well as the groups D0 and A20 in terms of the impact of attachment type and screw on torque reduction percentage (p<0.001), while there was no significant difference between groups A0 and A20 (p<0.96) (Table 2).

Table 2. Post-hoc test results of examining the effect of abutment and screw on the percentage of torque reduction

Tukey's multiple comparisons test	Mean difference (95% CI)	Mean 1	Mean 2	Adjusted p-value
D0 vs. A0	-14.21 (-17.88 to -10.55)	11.76	25.97	<0.001
D0 vs. A20	-13.80 (-17.46 to -10.13)	11.76	25.56	<0.001
A0 vs. A20	0.42 (-3.25 to 4.08)	25.97	25.56	0.96

Abbreviations: CI: confidence interval.

Discussion

In this study, we investigated the amount of reverse torque reduction in Angulated Screw Channel system. This system allows dentists to use screw-retained implant crowns in unfavorable anatomical conditions. Also, several tightening protocols and their effect on reverse torque reduction have been investigated. We found a significant difference in those groups using Ti-base angled screw channel abutment from the Arum dental company with zero- and 20-degree angles compared to the DIO dental company with zero-degree angles.

For screw-retained implant-supported restorations, there is a noted increase in reported mechanical complications in the literature. However, this therapeutic approach remains trustworthy, presenting benefits like straightforward removal and the absence of leftover cement—a potential contributor to peri-implant diseases—compared to cement-retained implant-supported restorations[16,17]. The ASC system introduces the possibility of using screw-retained restorations where cement-retained ones were the only option due to the screw access position, enabling an optimized placement for the screw access channel[16,17]. Various studies have been done on different companies that offer the ASC system. In studies, the screw access angle was established using three methods: firstly, used Ti-based abutments followed by crown design with CAD-CAM[8,15-17]; secondly, making wax-up and casting the crown over it[18]; and lastly, using a printed template as a guide[19-21]. In our study, to enhance precision, Ti-based abutments followed by crown design with CADCAM were employed.

Ensuring the correct torque and achieving sufficient preload provides greater confidence[22]. Each manufacturer has its recommended torque value. In this study, for the DIO company, it is 30 Ncm, and for the ARUM company, it is 20 Ncm.

The ASC-designed crowns permit the hexalobular driver to exert torque at angles from 0 to 25 degrees[17]. In this study, following the manufacturer's guidelines, we applied a maximum angle of 20 degrees. Our findings indicated a significant statis-

tical variance between the D0 and A0 groups and between the D0 and A20 groups. However, no significant difference was discerned between the A0 and A20 groups. In addition to the result mentioned above, a comparison between D0, A0, and A20 within each tightening protocol also revealed significant outcomes. Across all four tightening protocols, the percentage torque reduction in D0 was less than in both A0 and A20. However, no notable statistical difference was observed between the A0 and A20 groups. The study by Y.-H. Chen et al.[17] compared three angles (0, 15, 25 degrees), the study by Çakmak et al.[16] examined two angles (0, 25 degrees), and the study by Sparks[21] investigated three angles (0, 10, 20 degrees). None of these studies reported a significant statistical difference between the various angles, which aligns with the findings of our study.

Some other studies yielded different results, which may be attributed to variations in sample size, distinct ASC systems that possess different insertion torque and design features, and differences regarding the presence or absence of cyclic loading. The study by Chen et al.[17] indicated a linear trend between the degree of ASC and the percentage difference in removal torque. Opler et al.[20] examined five angles from 0 to 28 degrees (0, 10, 15, 25, 28) and demonstrated a 23% decrease in removal torque when using the maximum screw access channel angle. No significant statistical difference was observed between the angles of 0 and 15 degrees, suggesting that the contact surface between the screw head and the driver was minimal, resulting in minimal energy absorption through friction at the screw head. At angles of 25 and 28 degrees, the energy transfer leads to a reduced torque to the screw body, making the connection more susceptible to screw loosening. The study by Swamidass et al.[15] examined various ASC systems. All implants were loaded at an angle of 20 degrees. While this study did not report a significant statistical difference between the groups, it mentioned that systems with a higher insertion torque exhibit a lesser reduction in torque. This finding is consistent with the study by Mulla et al.[8], which reported comparable RTV values with conventional crowns with direct access for angled channel access systems that have higher recommended torque values. The difference observed between the DIO and ARUM abutments in our study might be due to the lower torque of the ARUM company (DIO 30 Ncm and ARUM 20 Ncm).

Various studies have attempted to minimize the settling effect through different screw-tightening protocols. The results of our study, regardless of the type of abutment, type of screw, and screw access angle, showed no significant statistical difference among the four tightening protocols. The highest percentage of torque reduction was observed in group T2 (22.96), and the lowest in group T4 (19.94). Comparisons between different tightening protocols applied in each group D0, A0, and A20 also did not indicate significant statistical outcomes. In this regad, Alnasser et al.[14] found no notable difference when tightening the abutment screw either twice with a 10-minute gap, with no gap, or just once. However, a distinct difference in removal torque emerged in the group subjected to three rounds of tightening and subsequent reverse torque. Siamos et al.[23] indicated that retightening post a 10-minute period augments the removal torque values. Khalili et al.[24] reported that retightening after a 10-minute interval reduces the decrease in torque

compared to the control group. The varying outcomes of these studies compared to our results might stem from differences in study design, the materials and design of screws used, the implant system, the type of connection area, and the application of cyclic loading.

It is noting that the Torque Meter used in this study was of the electric type, which might have influenced the lower torque values. Albayrak et al.[25] demonstrated that two mechanical devices, the spring-type and friction-type, were more accurate than electronic torque control devices. Faraj et al.[26] indicated that all three types of devices – electronic, conventional-style beam-type, and mechanical (hand-piece style) – produced satisfactory results, with the electronic device being more precise. Given that the torque leading to screw loosening might vary depending on the recommended insertion torque by the manufacturer and different electronic torque measuring devices, periodic calibration of the Digital Torque Meter is recommended[27].

The study has several limitations that should be noted and considered. First, our study was conducted with a limited number of samples, allowing only a restricted range of angles to be measured, and the effects of angles exceeding 20 degrees remain unspecified. Additionally, cyclic loading was not performed in our research, which could potentially influence the results.

In conclusion, there was no significant statistical difference in the percentage of removal torque reduction between different tightening protocols and between the angles of 0 and 20 degrees in the ASC system. There was significant statistical difference was shown in the percentage of removal torque reduction between the DIO company abutment and the ASC system at both 0 and 20-degree angles.

Acknowledgments

Not applicable (N/A).

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

Author Contribution

Fatemeh Bakhtiari: Study design, drafted the initial manuscript. **Ramin Negahdari:** Statistical analyses, drafted the initial manuscript. **Amirreza Babaloo:** Statistical analyses, drafted the initial manuscript. **Kasra Rahimipour**: Statistical analyses, drafted the initial manuscript. **Shima Ghasemi:** Study design, drafted the initial manuscript. All authors reviewed the drafted manuscript for critical content.. All authors actively participated in discussing the manuscript's findings and have revised and approved the final version of the manuscript.

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