EFFECT OF SCREW CHANNEL ANGULATION ON REVERSE TORQUE VALUES OF DENTAL IMPLANT ABUTMENT SCREWS

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ABSTRACT

EFFECT OF SCREW CHANNEL ANGULATION ON REVERSE TORQUE VALUES OF DENTAL IMPLANT ABUTMENT SCREWS M.S., SPECIALTY DEPT, YEAR

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Introduction: Angled screw channels were developed to maintain screw access/retrievability when implant position would otherwise preclude in-line screw channels. Implant manufacturers recommend torque values to achieve desired preload and clamping force of restorative components. However, the effect of angled screw channels on achieved insertion torque has been minimally researched. **Purpose**: To compare the reverse torque values of abutment screws tightened from three different angles. **Materials and Methods**: Implant abutment screws (48), abutments (3), and regular platform analogs (3) were divided into three angulation groups (n = 16/group). Custom guides of 0°, 10° and 20° were fabricated to verify screw insertion angulation prior to applying final insertion torque. The implant components for each group were assembled and all screws torqued to 35Ncm using a universal screwdriver in a manual torque wrench at the appropriate angle. Torque was manually repeated 10 minutes after initial torque. A digital gauge was then used to measure reverse torque at a position parallel (0°) to the implant analog. Reverse torque values were recorded and compared using one-way ANOVA and Tukey HSD post-hoc comparisons ($\alpha = 0.05$). **Results**: All reverse torque values were below the targeted torque value of 35Ncm, with some values in each angulation group below 10% of the target value. Mean reverse torque values in descending order from targeted torque value were: 10° group = 32.07 ±0.97 Ncm, 0° group = 31.16 ±1.12 Ncm, and 20° group = 30.08 ±0.88 Ncm. One-way ANOVA revealed significant differences between angulation groups ($p < 0.001$). Tukey HSD post hoc comparisons revealed the 3 angulation groups were significantly different from each other ($p = 0.033$, $p = 0.011$, $p < 0.001$). **Conclusions**: This in vitro study found: 1) All reverse torque values did not reach the targeted torque value of 35Ncm, and 2) Mean screw reverse torque values were significantly influenced by screwdriver insertion angulation.

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Chapter I: Introduction

Implant supported restorations are a viable means to replace missing teeth[1]. Implant supported restorations can be retained by screws or cement with each option having its advantages and disadvantages. Benefits of screw retained implant restorations include: ease of restoration repair and minimizing the risk of peri-implantitis related to residual cement[2]. However, screw retention is not always possible due to factors such as maligned implant angulation resulting in an unaesthetic screw access.

Careful prosthetic driven treatment planning facilitates proper implant positioning and ideal screw access. Traditionally, cement retained restorations on custom abutments were used when implant angulation limited screw access to an unfavorable area compromising esthetics or function[3]. Options to maintain screw retrievability include using a lingual set screw[4], but the fabrication process for a lingual set screw restoration is technically challenging, time consuming, and incurs additional cost[4]. Another option is to alter angulation of the screw channel within the restoration to achieve ideal screw access/retrievability, while maintaining abutment screw alignment with the implant. There are many restorative systems currently using the angled screw channel concept in the market. They include milled cobalt-chrome Cara I-Butments (Heraeus Kulzer), Angulated Screw Channel restorations (ASC) (Nobel Biocare), and castable Dynamic Abutments (Talladium International Implantology) for single unit anterior or posterior zirconia restorations, and the Angulated Screw Access (ASA) concept for the Atlantis bridge and hybrid prosthesis (DENSPLY)[3,5,6]. Cara I-Butment and ASC can change the screw channel 25 degrees from the implant axis, while Angulated Screw Access can change screw access 30 degrees[6].

Abutment screw loosening is the most common mechanical complication in screw retained restorations and custom abutments[7]. An average of 6% screw loosening in implant restorations has been reported[1]. A loose abutment screw can lead to biological or mechanical complications such bacterial colonization along the abutment-implant junction, crestal bone loss, and fracture of the screw, abutment, or implant body[1]. External forces can increase the risk of screw loosening, such as parafunctional habits, arch position, cantilevers, occlusal designs, implant positions, non-passive seating, and inadequate or excessive screw torque[1]. When torque is applied to an abutment screw, it elongates the screw producing a tensile force called the preload between the shank and screw threads[8,9]. When adequate preload is achieved, elastic recovery of screw creates the clamping force to hold the restoration or abutment to the implant[2]. Each implant system has different recommended torque values for each abutment screw and should be followed accordingly. As torque decreases below manufacturer's recommended values, there is insufficient clamping force which can result in screw loosening[1]. Conversely, when too much torque is applied, screws can undergo plastic deformation resulting in the loss of clamping force[1,8].

Torque is a force that acts to produce rotation. It is dependent on the magnitude of the force (F) and lever arm (l). Lever arm is defined as the perpendicular distance from axis of rotation to the line of action of the force[10]. When force is applied at an angle, torque can also be written as T = F*r*sin(theta), where F = applied force, r = radius from axis of rotation, and angle theta being degrees with respect to the action of the force[10]. Theoretically, 100% of applied force is transferred to the screw when the screwdriver is in line with the abutment screw (torque wrench perpendicular at 90 degrees). Therefore, less torque is expected when insertion angle is shifted 20 degrees away. Some manufacturers have claimed that there are no differences of torque applied from different angulations

The purpose of this study was to compare reverse torque values of abutment screws tightened to manufacturer's recommended torque value from three different angles (0°, 10°, and 20°). The null hypothesis postulates that there are no differences between reverse torque values of abutment screws tightened from these three different angles.

Chapter II: Materials and Methods

Forty-eight machined abutment screws (iMilling, reference #SCNBRUV, Chantilly, VA, USA), three 4.3mm regular platform S-Link abutments (iMilling, reference #SLNBR43) that allow angle correction up to 20 degrees, and three regular platform implant analogs (iMilling, reference #3DNBR43) were divided into 3 angulation groups (0°, 10°, and 20°). Sample size (n = 16/group) was determined with a power analysis ($\alpha = 0.05$).

Implant analogs were embedded in titanium implant analog holders (Ti6Al4V ELI, Arcam EBM, Sweden), and secured using autopolymerizing methyl methacrylate (Alike, GC America, Alsip, IL, USA). Screws in each group were hand tightened using a special screwdriver with round flutes (Universal Angled Driver, iMilling, reference #ASDUVL) to hold abutments to implant analogs. Three 3D printed angulation guides (Dental LT Clear, Formlabs, Somerville, MA), one for each angulation were made to verify specified insertion angulation, and secured to each abutment prior to applying final insertion torque. All screws were torqued to manufacturer's recommended torque of 35Ncm using the universal screwdriver in a manual restorative torque wrench (Zimmer Biomet, Carlsbad, CA, USA, reference #TWR), which was calibrated by the manufacturer. Ten minutes after the initial torque, each screw was re-torqued to 35Ncm with the manual torque wrench to minimize embedment relaxation and the settling effect. After another minute, the universal screwdriver secured in 3-jaw chuck of the digital torque gauge (Tohnichi Torque Gauge, model BTGE50CN-G, Buffalo Grove, IL, USA) was used to measure the reverse torque value of each sample in Ncm from the 0 degrees position parallel to the implant analog. Entire experiment was operated by the same prosthodontics resident.

Reverse torque values were calculated and compared using one-way analysis of variance (ANOVA). Tukey HSD was used as a post-hoc test ($\alpha = 0.05$). All statistical analyses were performed using statistical software (IBM SPSS for Windows, version 24)

Fig. 1. Universal Angled Driver, abutment screw, S-Link abutment, and implant analog

Fig. 2. Manual restorative torque wrench

Fig 3. Digital torque gauge

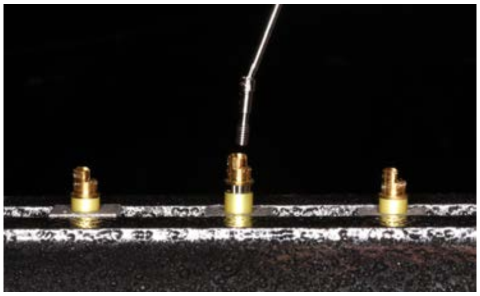

Fig. 4. Samples embedded in titanium holders

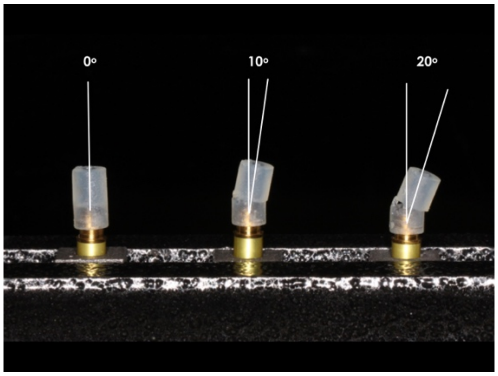

Fig. 5. 3D printed angulation guides secured to abutments

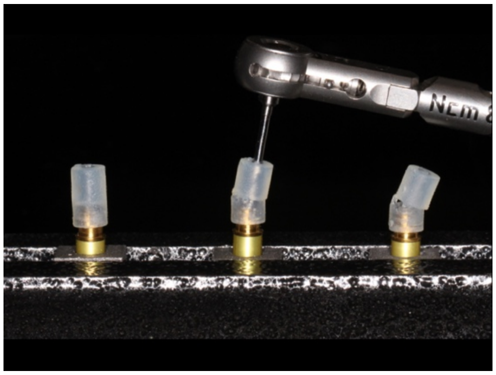

Fig. 6. Torque applied through angulation guides

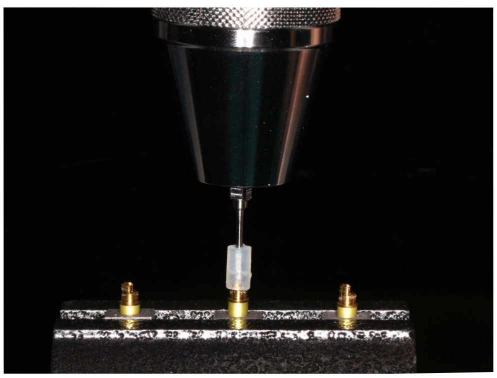

Fig. 7. Reverse torque value measured with digital torque gauge

Chapter III: Results

Abutment screw reverse torque values (RTVs) are represented in Figure 8. In this study, the 10° group had the highest mean RTV (32.07 ±0.97Ncm), and the 20° group had the lowest RTV (30.09 ±0.88Ncm). The 0° group had RTV of 31.16 ±1.12 Ncm. One-way ANOVA showed significant differences between angulation groups (p <0.001), and Tukey HSD post hoc analysis found that all 3 angulation groups were significant from each other. The highest overall RTV was 34.85Ncm from the 10° group, and the lowest overall reverse torque value was 28.90Ncm at 20°. All reverse torque values were below the target insertion torque of 35Ncm.

	RTV (Ncm) - 0°	**RTV (Ncm) - 10°**	**RTV (Ncm) - 20°**
Screw #1	33.20	32.05	30.95
Screw #2	30.10	33.35	32.05
Screw #3	31.60	31.80	30.50
Screw #4	31.70	31.60	29.65
Screw #5	30.65	32.80	29.85
Screw #6	31.15	31.20	29.35
Screw #7	31.70	32.30	30.35
Screw #8	30.15	31.90	30.05
Screw #9	33.20	34.85	29.20
Screw #10	30.80	31.90	30.80
Screw #11	31.55	31.10	31.55
Screw #12	29.70	32.45	29.50
Screw #13	30.55	31.95	29.70
Screw #14	31.50	31.45	29.50
Screw #15	31.80	31.35	29.50
Screw #16	29.15	31.10	28.90
Mean	31.16 ±1.12	32.07 ±0.97	30.09 ±0.88

Table 1. Reverse torque values of implant abutment screws

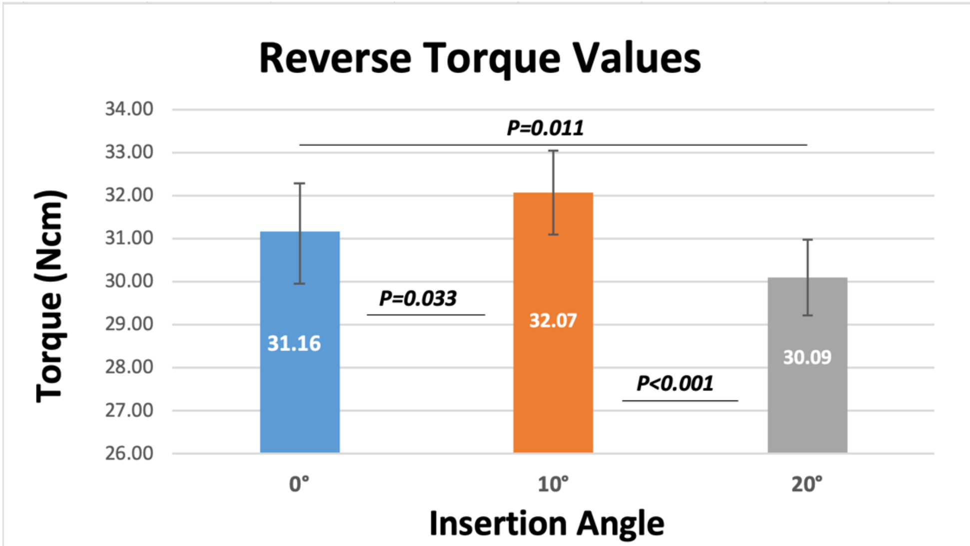

Fig. 8. Mean Reverse Torque Values

Chapter IV: Discussion

Mean abutment screw RTVs of all 3 angulation groups were statistically significant from each other, therefore the null hypothesis was rejected. Comparative studies involving insertion torque application from different angulations are currently limited. However, in a study by Goldberg et al., it compared the removal torque values and fracture strength of abutment screws between 3 dynamic abutment angulation groups (0°, 20°, and 28°), and found that the 0° group showed highest RTVs, while the 28° showed the lowest RTVs[11]. All groups were not statistically significant from each other, and the author suggested that increased nonaxial loading created higher tensile forces to the screw[11].

In this study, the 20° group showed the lowest RTV as expected due to the loss of applied torque as a component of the increased insertion torque angle. However, 10° group showed the highest RTV and it may be contributed to the mechanical design and more intimate engagement between the screwdriver and abutment screw at that angulation.

All RTVs recorded in this study were below the target torque value of 35Ncm. The lower values can be attributed to the screw material, fit between the screwdriver, abutment, implant analog, accuracy of mechanical torque-limiting device, and/or accommodating for the settling effect under load. It has been hypothesized that when torque is applied during screw tightening, 2-10% of the initial preload can be lost due to microroughness between the abutment and implant surfaces[12]. Siamos et al. recommended retightening the abutment screws 10 minutes after the first torque application to help minimize the settling effect and decrease screw loosening[8]. Mechanical torque-limiting device used in this study may have also contributed to the lower torque values. Albayrak et al. showed that both spring-type and friction-type mechanical devices were more accurate than electronic torque-control devices, but all of tested torque devices fell below the target torque values[13]. In another study comparing the accuracy of spring-type and friction-type mechanical torque limiting devices, it was found that there was no difference between the 6 mechanical torque limiting devices, and that the Zimmer Dental friction-style torque-limiting device used in this study was one of the more accurate devices[14]. L'Homme-Langois et al. also found that torque values from all 6 devices fell within 10% of the target torque value[14]. However, in this present study, there were RTVs from all angulation groups that fell below 10% of the target torque value set by the manufacturer.

The present study has a number of limitations. First, torque-limiting device used in this study has been used clinically for a year since calibration by the manufacturer, where clinical use may have affected its accuracy. Second, operator error may have affected accuracy of this study due to the tactile control of the applied torque. Third, the same lab analog was repeatedly used for each angulation group, although RTVs did not show linear decrease in value. The angled screw channel concept is becoming more popular in the market, and each implant system has its own driver, screw, abutment, and implant design. Providers need to be aware of these differences and possible variation in performance under clinical conditions. Further studies are needed to evaluate different angled screw channel systems from various manufacturers in simulated clinical conditions, such as testing under cyclic loading in wet environments[15].

Chapter V: Conclusions

Based on the findings of this in vitro study, the following conclusions were drawn:

1) All reverse torque values did not reach the targeted torque value of 35Ncm.

2) Mean screw reverse torque values were significantly influenced by screwdriver insertion angulation.

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