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Effect of tightening torque on the marginal adaptation of cement-retained implant-supported fixed dental prostheses

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ABSTRACT

Background: The final position of the abutment changes with the amount of tightening torque. This could eventually lead to loss of passivity and marginal misfit of prostheses. The aim of this study was to evaluate the effect of three different tightening torques on the marginal adaptation of 3-unit cement-retained implant-supported fixed dental prostheses (FDPs).
Materials and Methods: Two implants (Straumann) were inserted in an acrylic block so that one of the implants was placed vertically and the other at a 15° vertical angle. A straight abutment and a 15° angulated abutment were connected to the vertically and obliquely installed implants, respectively, so that the two abutments were parallel. Then, 10 cement-retained FDPs were waxed and cast. Abutments were tightened with 10, 20, and 35 Ncm torques, respectively. Following each tightening torque, FDPs were luted on respective abutments with temporary cement. The marginal adaptation of the retainers was evaluated using stereomicroscope. FDPs were then removed from the abutments and were sectioned at the connector sites. The retainers were luted again on their respective abutments. Luting procedures and marginal adaptation measurement were repeated. Data were analyzed by ANOVA and least significant difference tests ($\alpha = 0.05$). After cutting the FDP connectors, the independent samples *t*-test was used to compare misfit values ($\alpha = 0.05$).
Results: Following 10, 20, and 35 Ncm tightening torques, the marginal discrepancy of the retainers of FDPs significantly increased ($P < 0.05$). There was no significant difference between the marginal discrepancies of these two retainers ($P > 0.05$). The marginal gap values of angulated abutment retainers (ANRs) were significantly higher than those of the straight abutment after cutting the connectors ($P = 0.026$).
Conclusion: Within the limitations of this study, the marginal misfit of cement-retained FDPs increased continuously when the tightening torque increased. After cutting the connectors, the marginal misfit of the ANRs was higher than those of the straight abutment retainers.

Key Words: Dental implants, fixed partial denture, implant-supported prosthesis, marginal adaptation, torque

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INTRODUCTION

Internal conical implant-abutment connection is becoming more popular because it provides a more stable connection and increases resistance to screw loosening.[1-4] Moreover, many studies have indicated that internal conical connections have potential mechanical advantages compared to external connections.[5-7] Nevertheless, for implant systems with internal conical connections, a certain amount of axial abutment displacement occurs during tightening, so that as the level of tightening torque increases, the axial displacement of the abutment increases.[8-12] The axial displacement of the internal conical abutments is attributed to three

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factors: Wedge effect, settling effect, and machining tolerance.[10]

In addition, horizontal displacement of an abutment from its original position might occur during screw tightening, and the amount of this displacement is influenced by the extent of rotational freedom. Rotational displacement of an abutment is possible in all implant systems, depending on their geometric design and machining tolerance.[13-16] The dimension of every machined component may differ from its exact dimension, and this difference is due to machining tolerance. It has been shown that machining tolerances have a major effect on the extent of the clearance fit between the components.[17]

Implant manufacturers do not offer the necessary information concerning the amount of axial and rotational displacement of abutments while the tightening torque is applied. For the implant-level impression technique, the question of perfect passive fit of the superstructure has been raised. In the laboratory, abutments are tightened on implant replicas using a handheld screwdriver, inducing variable undetermined tightening torque.[18] In the oral cavity, abutments are tightened into the implant with a torque ranging from 15 to 35 Ncm, depending on the implant system guide. Thus, if the axial and rotational displacement of the abutment change with the amount of tightening torque, the final position of the abutment could differ on the master cast and intraorally. This could eventually result in loss of passivity and marginal misfit of implant prostheses.[8,9,13,19] Little is known about the effect of abutment displacement on marginal discrepancy of cement-retained implant-supported fixed dental prostheses (FDPs). The aim of this study was to evaluate the influence of three different levels of tightening torques on the marginal adaptation of 3-unit cement-retained implant-supported FDPs. The null hypothesis was that tightening torques would not affect the marginal adaptation of cement-retained implant-supported FDPs.

MATERIALS AND METHODS

Two 4.1 mm × 12 mm implants (043.922S, Straumann AG, Basel, Switzerland) were inserted in an acrylic block. One of the implants was placed vertically and the other at a 15° vertical angle using a surveyor so that they were 15 mm apart. A straight two-piece abutment (048.605, Straumann) and a 15° angulated abutment (048.612, Straumann) were connected to the vertically and obliquely installed implant, respectively, so that the abutments were parallel [Figure 1a]. To connect the abutments, screws were tightened with no force.

Prefabricated plastic copings were seated on the abutments and waxed using the conventional technique. Ten wax patterns for the 3-unit FDPs with an intermediate pontic (spanning the first premolar to the first molar) were prepared [Figure 1b]. A custom silicon mold was made over the first FDP wax pattern and used to reproduce the dimensions. The wax patterns were sprued and invested with a phosphate-bonded investment (Bellavest T Materials, Bego, Bremen, Germany). Casting was done with Ni-Cr base-metal alloy (Supercast, Thermabond Alloy, Los Angeles, USA) using a centrifugal casting machine (Ductaron, KFD Dental, Tehran, Iran). After divestment and removal of sprues, metal frameworks were airborne particle abraded using 50 μm aluminum oxide particles at a distance of 10 mm for 10 s at 2.7 bar pressure in a sandblasting unit (Basic Classic, Renfert, Germany) to eliminate residual investment. The inner surface of frameworks was inspected under an optical microscope (Dino Lite, New Taipei City, Taiwan) with ×10 magnification. The irregularities that resulted from the casting procedures were adjusted with a carbide bur. Abutments were then tightened using a 10 Ncm level torque wrench. The frameworks were luted on their corresponding abutments with a thin layer of temporary cement (Temp Bond, Kerr, Salerno, Italy). A hydraulic clamp was used to maintain a seating load of 4.5 kg for 4 min.

Specimens were mounted on a special clamp and observed under a stereomicroscope at ×250 magnification to evaluate vertical marginal discrepancy [Figure 2]. Marks were made on each abutment to identify the microscope measurement points. The measurements were made at three predetermined reference points at the mid-buccal, mid-lingual, and mid-lateral side of each abutment. The averages of

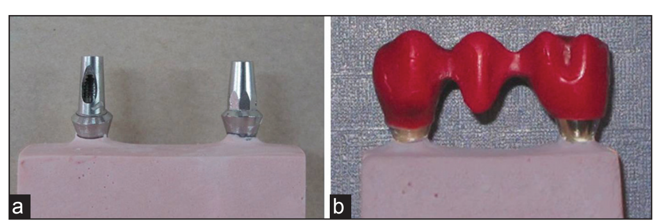

Figure 1: (a) Straight and angulated abutments were connected to their respective implants (b) wax pattern of cement-retained 3-unit fixed dental prosthese.

these three measurements were considered as the vertical gap value of each abutment retainer. After measurement of marginal gap, specimens were removed from the clamp and metal frameworks were dislodged from their respective abutments. The frameworks were then placed in an ultrasonic bath (Vitasonic II, VITA Zahnfabrik H. Rauter GmbH and Co., Bad Sackingen, Germany) for 5 min to clean the inner surface of the frameworks from the remaining cement.

Afterward, abutments were tightened using a torque wrench initially with 20 Ncm and then with 35 Ncm. Following the tightening torque in each step, frameworks were seated on their corresponding abutments in the same manner as previously described measuring the marginal gap on the former reference points [Figure 2]. Frameworks were then removed from the abutments and were sectioned at the connector sites with a carborundum disc (Dentorium, New York, USA) so that the pontics were separated from the retainers. Two retainers of each framework were then placed and luted on their respective abutments so that the marks that had been made previously on the implants and abutments were located along each other. The luting procedures were repeated in the same manner as previously described for FDPs.

The specimens were examined under a stereomicroscope to measure the vertical marginal gap in the predetermined reference points. The mean marginal misfit of the straight abutment retainer (STR) and angulated abutment retainer (ANR) was calculated. Normal data distribution was confirmed by the Shaprio-Wilk test. A repeated measure ANOVA was applied to analyze the effect of the three tightening torques on the marginal adaptation. The least significant difference test was applied for *post-hoc* comparisons. After cutting the FDP connectors, the independent samples *t*-test was used to compare data. A significance level of $P < 0.05$ was used for all comparisons.

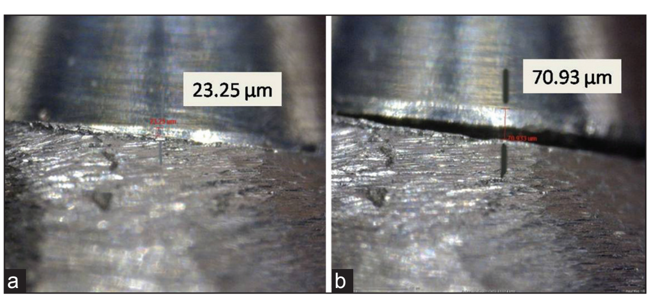

Figure 2: Vertical marginal discrepancy of the buccal side of one of the angulated abutment retainers following 20 (a) and 35 Ncm (b) torque tightening (×250).

RESULTS

The mean marginal misfit values for STR and ANR with three applied torque levels are shown in Table 1. There were significant differences between marginal gaps of the FDPs following three applied torque levels [Table 2]. The mean marginal gaps of both STR and ANR significantly increased following the application of 10, 20, and 35 Ncm torque tightening ($P < 0.05$). No statistically significant differences were found between the marginal misfit of the STRs and ANRs at torque tightening of 10, 20, and 35 Ncm ($P = 0.860$, $P = 0.111$, and $P = 0.205$, respectively). Nevertheless, the mean marginal misfit of ANRs was significantly more than those of STRs after cutting the FDP connectors ($P < 0.05$) [Table 1].

DISCUSSION

According to the results of this study, the marginal misfit of FDP retainers increased continuously when the tightening torque increased from 10 to 35 Ncm. Thus, the null hypothesis that the tightening torques would not affect the marginal adaptation of cement-retained implant-supported FDPs was rejected.

Many investigators have studied the marginal gap between the abutment and its superstructure, and it is considered as a criterion for implant long-term success and mechanical complications.[20-22] The penetration of potentially pathologic bacteria through

Table 1: Mean (SD) values of vertical marginal dicrepancy (μm) of the retainers following tightening torques and after cutting the connectors

Retainer	Tightening torque			After sectioning the connectors
	10 Ncm	20 Ncm	35 Ncm	
STR	41.3 (25.4)$^{B}_{a}$	61.8 (25.2)$^{C}_{a}$	63 (24.1)$^{D}_{a}$	21.4 (11)$^{A}_{a}$
ANR	41.7 (19.5)$^{B}_{a}$	70.3 (16.7)$^{C}_{a}$	80 (14.8)$^{D}_{a}$	32.1 (8.2)$^{A}_{b}$

SD: Standard deviation; STR: Straight abutment retainer; ANR: Angulated abutment retainer. Different uppercase letters in the row mean the gap values are significantly different ($P < 0.05$); Different lowercase letters in the column mean the gap values are significantly different ($P < 0.05$)

Table 2: Results of repeated measure ANOVA

Source	df	Mean square	F	P
STR	2	2584.3	82.5	<0.001
ANR	2	6862.5	280.5	<0.001

STR: Straight abutment retainer; ANR: Angulated abutment retainer gaps associated with implant-supported prostheses may also contribute to soft tissue inflammation.[23] Depending upon the type of abutment, the marginal fit of an implant-supported single crown ranges from 50 to 70 μm.[9] Although cement-retained prostheses have been widely used in implant dentistry, there is little scientific data concerning their tolerated marginal discrepancy because the tolerated misfit is mostly defined for screw-retained restoration with a very different biomechanical behavior.[24,25] However, a marginal fit discrepancy of 50 μm or less is currently acceptable for a cement-retained implant prosthesis.[8,26]

In this study, using a 10 Ncm tightening torque, the mean vertical marginal gap was 41.3 and 41.7 μm for STR and ANR, respectively, which are in an acceptable range. Subsequent to the application of the 20 and 35 Ncm tightening torques, the mean vertical marginal gap of the STRs and ANRs significantly increased and reached the amounts greater than the acceptable range (<50 μm).

The bidirectional rotational freedom (α) of the Straumann implant system was calculated to be 3.7° at a clearance of 20 μm between implant and abutment.[14,15] Semper *et al.*[13] showed that this extent of rotational freedom of Straumann implants results in a 50 μm up to 1.87 mm vertical marginal gap in a 15° angulated abutment superstructure and 45 up to 266 μm in a straight abutment superstructure, depending on internal gap values. In the current study, following 20 and 35 Ncm tightening torques, the mean vertical marginal gap of the STRs and ANRs increased to amounts that were within the aforementioned range [Table 1].

In FDPs, applying a 35 Ncm tightening torque did not show a significant difference in the marginal gap of the STRs and ANRs. However, after separating the connectors, the marginal misfit was significantly higher in the ANR compared to the STR. This finding could be attributed to the fact that the rotational displacement of the angulated abutment during tightening causes three-dimensional changes in the position of the abutment, and this leads to a larger marginal gap in the ANR subsequent to the separation of the connectors.[13] However, the insignificant difference of marginal gap between STRs and ANRs before separation of the connectors can be due to the fact that in one-piece FDPs, the smallest displacement in one abutment affects both retainers. Therefore, a larger increase in the marginal gap in an ANR can indirectly increase the marginal gap in the STR abutment, leading to an insignificant difference of marginal misfit between STRs and ANRs.

It is important to consider the cement space in cement-retained implant restorations. Cement space may be sufficient to compensate for abutment-superstructure inaccuracies in a single restoration so that the abutment's positional displacement has no effect on the marginal fit.[8] However, in this study, in which a fixed dental prosthesis was fabricated over two abutments, a different situation was encountered. Cement space might not be sufficient to prevent abutment-superstructure interfaces resulting from abutment positional displacement.

In a clinical situation, after applying the final torque, superstructure inaccuracy can be revealed in the form of occlusal interferences or changes in the tightness of proximal contacts.[12,13] In the present study, the frameworks were seated with controlled constant pressure, whereas in the oral cavity when the superstructure is commonly placed with finger or biting pressure on corresponding abutments, marginal gap may decrease due to increased seating force. Nevertheless, this may result in strain development within components or inadequate passive fit.[12,13]

According to the findings of this study, clinicians using implant-level impression technique for an extensive fixed prosthesis should consider the possibility of loss of passivity during final torque tightening. It seems that the abutment level impression technique is more effective to achieve passive fit compared to the implant level impression.[8] Thus, for a single crown, after applying the final tightening torque, it is recommended to inspect the inner surfaces of the superstructure using disclosing agents to ensure complete seating.

In order to achieve passive casting in implant-supported FDPs, it is suggested that the superstructure be cast in a smaller separated multiunit. After applying the final tightening torque recommended by the manufacture, the separate retainers are seated on their retainer abutments and are then indexed and soldered.

Vertical marginal inaccuracies of frameworks for cement-retained FDPs can be influenced by alloy type. In the absence of passivity and response to occlusal forces, plastic deformation may occur in metal frameworks depending on alloy type.[27,28] This may influence the restoration seating and marginal discrepancy. Thus, different values of marginal misfit may have been obtained if another alloy type had been used.

In this study, the effect of tightening torque on the marginal adaptation of 3-unit FDPs on one implant system was simulated. Since the correlation between the level of tightening torque and stress distribution in cement-retained implant prostheses is unclear, further photoelastic studies are needed to evaluate the stress distribution pattern and magnitude in the supporting tissues around implants of cement-retained FDPs.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

1. The marginal misfit of cement-retained FDPs increased continuously when the tightening torque increased from 10 to 35 Ncm.
2. In FDPs, there were no significant differences between the marginal misfit of the straight and ANRs at torque tightening of 10, 20, and 35 Ncm.
3. After cutting the FDP connectors, the marginal misfit of the ANRs was higher than those of the STRs.

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