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Effect of Impression Techniques on Screw Loosening for Screw Retained Implant Supported Restorations Under Cyclic Loading: "An in-Vitro Study"

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ABSTRACT

Background: screw loosening is a common mechanical complication in dental implants. Ensuring stable connections between implant components is crucial for long-term success of the treatment. ***Aim****:* The purpose of this in-vitro study was to assess the screw loosening of two implant impression techniques (Conventional vs digital) by measuring the removal torque value (RTV) of screw abutment before and after subjecting the specimens to cyclic loading. ***Materials and methods****:* twenty-four implant fixtures were placed in epoxy resin blocks. Implant fixtures were divided into two groups (n= 12); where half of the samples had open tray conventional impression technique for recording implant fixture position using transfer coping (group C), while the other half had digital impressions using scan bodies (group D). Then screw -retained zirconia crowns were fabricated for all the samples using the CAD-CAM technique. The suprastructures were screwed with 30 Ncm tightening torque; then they were subjected to cyclic loading for 37500 cycles. A digital torque gauge was used to record the removal of torque values before and after cyclic loading. The removal torque loss ratio was calculated before and after cyclic loading and analyzed using the SPSS statistical analysis. ***Results****:* For Group C, the post load removal torque values (22.15±0.77) (Ncm) had statistically significant higher values than Group D (20.63±0.91) (Ncm). ***Conclusion:*** Within the limitations of this study, the results showed that the screw retained suprastructure fabricated from conventional impression technique showed less liability for screw loosening when cyclic loading than those fabricated from digital ones.

Keywords*:* Screw Loosening, Cyclic Loading, Implant Impression, Digital Torque Gauge, Removal Torque

INTRODUCTION

The problem of restoring missing teeth can be treated with either tooth-supported or implant-supported fixed dental prostheses (FDP). These treatment options have various documented longevities with a high success rate. The implant-supported fixed prosthesis

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is considered a more conservative option, that is because the implant provided restorations of the missing teeth form and function without the affection of the adjacent teeth yet, there are complications, which could be either biological or technical risks that should be considered during treatment planning. Mechanical issues such as screw loosening, fracture, and prosthesis breakage, along with biological problems like tissue inflammation, can result from improper fit.[1]

Incidence of screw loosening as the most common mechanical complication was reported to be approximately 8.8% after five years,[2] while another study reported the percentage to be 14%.[3] That might be caused by inappropriate tightening torque, vibrating micro-movement because of loading during function, fatigue of the screw, settling effect, inappropriate implant position, improper occlusal design or crown anatomy, slight differences in fit and accuracy, tension on abutment from ill-fitting restorations, as well as improper screw design.[3]

To achieve a passive fit, and to prevent complications such as screw loosening, bone loss, and abutment fracture during function, accurate impressions and casts are essential and mandatory to a successful outcome in any implant-supported prosthesis. The conventional impression technique with transfer copings is a well-documented method for fabricating the fixed implant-supported reconstruction. However, the conventional techniques result in some degree of error manifested as the possibility of displacement of the implant analogue compared to the actual intraoral position.[4]

An alternative to the conventional approach is the digital impression technique, through which the impression is recorded virtually with either an intraoral or extraoral optical scanner system. Intraoral scanners have the advantages of elimination of tray selection, reduced risks of distortion during impression making, pouring, disinfecting, and transferring to the laboratory, besides patient comfort and acceptance and finally, storage as digital information, leading to better efficiency and reduced costs. All these advantages are offered by the digital technique with the same accuracy levels as the conventional impression and result in a clinically acceptable fit.[5]

So, it was worth comparing the effect of the digital impression technique versus the conventional impression technique in recording implant position in terms of susceptibility of screw loosening in screw-retained implant-supported restorations.

The null hypothesis was that there would be no difference in the degree of screw loosening of implant-supported screw-retained zirconia restoration fabricated using either conventional implant impression technique or digital ones after being subjected to cyclic loading.

MATERIALS AND METHODS

A total of twenty-four zirconia screw-retained restorations (n=24) were fabricated on internal hex implant fixtures and divided into two groups (n=12) according to the impression technique used: Conventional impression technique group (Group C), Digital impression technique group (Group D).

Implant fixtures were placed in the center of epoxy resin blocks (20mm long, 20mm wide, and 3mm thick) (**Figure 1**); the epoxy resin was mixed according to the manufacturer's instructions and poured in a silicon mold housed with an impression coping to standardize the implant fixtures position in the blocks.

Figure (1): The implant fixture in the middle of the epoxy resin block.

Group C implant fixture was fitted with an open tray transfer coping, followed by the application of a one-step impression technique using an additional silicon impression material (Elite HD). A light body was injected around the transfer coping attached to the implant, while a heavy body was applied in a sectional stainless tray as per the manufacturer's guidelines. The tray was then positioned over the transfer coping, ensuring the emergence of the long screw of the transfer coping from the tray opening (**Figure 2, A**). After setting, the transfer coping screw was removed, and the impression, with the coping inside, was taken out. Subsequently, the implant analog was attached to the transfer coping. The impression was poured with Type IV stone and then scanned using a Launca dl-206 scanner to generate an STL file for the crowns' construction.

For Group D, a scan body (Neobiotech) was attached to each implant fixture in the epoxy mold (**Figure 2, B**), and optispray (Sirona, Erlangen, Germany) was applied to the mold to prevent the reflectiveness from the glossiness of the epoxy material to ensure accurate scanning with the intraoral scanner. Then, an intraoral camera, Medit i600 (Medit, Republic of Korea), was used to scan the body to start designing using EXOCAD and construction of a CAD/CAM constructed zirconia crown (Katana, Kurary, Japan). Full scanning data was obtained as an STL file and was sent to the laboratory for fabrication of the crowns using the CAD/CAM technique.

The crowns were designed as an upper central incisor zirconia crown with a screw hole opening in the cingulum area of the crown along with the abutment screw channel.

After designing, all zirconia crowns were constructed using 5-axis milling machine (Imes-Icore 250i, CORiTEC 250i Loader PRO, Germeany), and cemented on their corresponding abutments using glass ionomer cement.

The whole crown-abutment assemblies were screwed into their corresponding implants (**Figure 2, C**).

For the purpose of standardization of the screwing torque, the implant screwdriver (Neobiotech, Republic of Korea) was attached to the digital torque gauge (HTG2-200Nc, IMADA, Toyohashi, Japan) (**Figure 3**) that was used to tighten the abutments at 30 N cm according to the manufacturer's instructions. Then after 10 min, the screws were retightened again using the same tightening torque to compensate for the loss of preload caused by the surface settling of the interface.[6] Then, 10 min later, the screws were unscrewed, and the removal torque was measured using the digital torque gauge. This removal torque was recorded for each screw as the initial removal torque before cyclic loading. The screws were screwed again at 30 Ncm, then retighted again after 10 min; Teflon was placed in the screw access holes of the abutments and covered with flowable

A B C

Figure (2):
A: open tray impression techqniue using addition silicon.
B: Neobiotech scan body attached to the implant fixture in the epoxy resin block.
C: Screwentable zirconia implant supported crown in the epoxy resin block.

composite.

Figure (3): Digital torque gauge.

All samples were mounted in ROBOTA chewing simulator[7] (**Figure 4**); a weight of 5 kg attached to a rod (which is equivalent to 50 N of chewing force) was used to exert load with a 45° angle at the cingulum area of the crowns to simulate the loading intraorally. The test was repeated 37500 times to clinically simulate 3 months.[8]

Then, the postload removal torque value was measured after cyclic loading using the same digital torque gauge and recorded.

Each loss ratio of removal torque was calculated using the following formula:[9]

1- <u>Loss ratio of removal torque before loading (%)</u>

It is the difference percentage between the value of tightening (30 Ncm) and the value needed to unscrew abutment screws before being subjected to cyclic loading.

$$= \frac{\text{Tightening torque} - \text{initial removal torque value}}{\text{Tightening torque}} \times 100 =$$

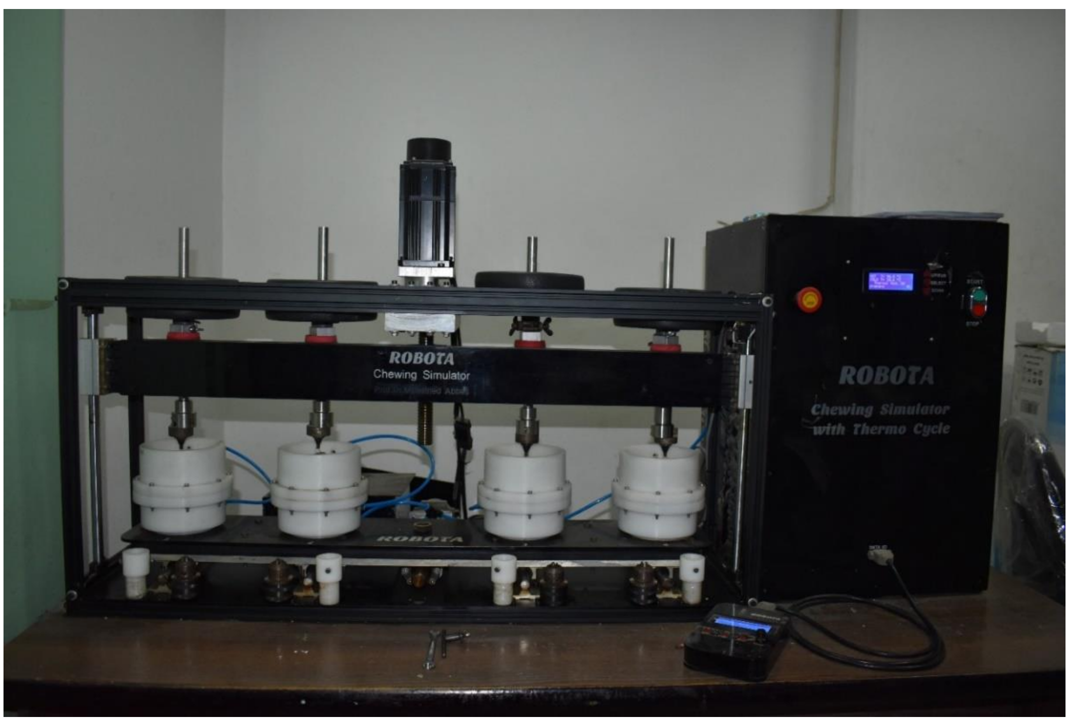


Figure (4): Robota chewing simulator device.

2- Loss ratio of removal torque after loading (%):

It is the difference percentage between the value of the tightening (30 Ncm) and the value needed to unscrew abutment screws after being subjected to cyclic loading.

$$= \frac{\text{Tightening torque} - \text{postload removal torque value}}{\text{Tightening torque}} \times 100 =$$

3- Loss ratio of removal torque between before and after loading (%):

It is the difference percentage between the value needed to unscrew abutment screws before and after loading. =

$$\frac{\text{initial removal torque value} - \text{postload removal torque value}}{\text{initial removal torque value}} \times 100 =$$

Numerical data values were presented as mean and standard deviation values, analyzed for normality using Shapiro-Wilk's test, were found to be normally distributed, and were analyzed using an independent t-test. The significance level was set at p<0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.2 for Windows.

RESULTS

The mean ± SD of post-load removal torque values and the loss ratio difference between the two groups are presented in (**Figure 5**) (**Table 1**).

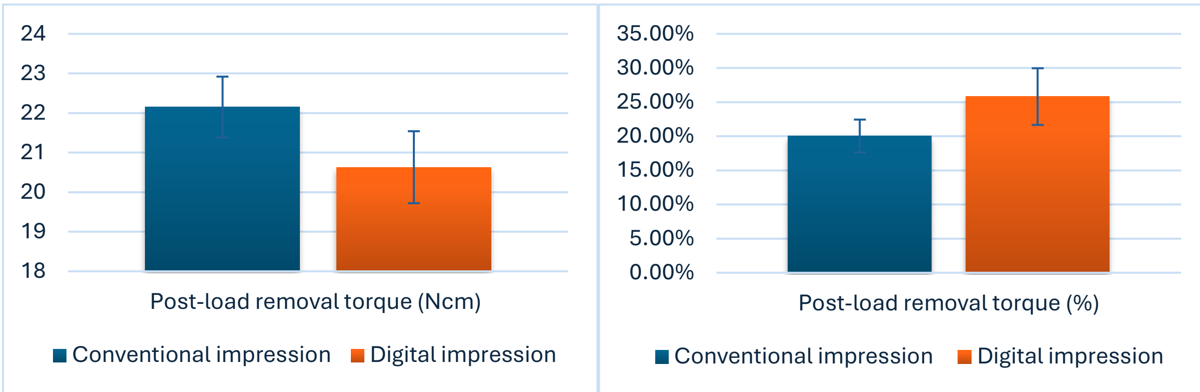
Results showed that implant-supported restorations fabricated using conventional impression technique had a significantly higher post-load removal torque (22.15±0.77) (Ncm) than those constructed using the digital impression (20.63±0.91) (Ncm) (p<0.001).

Moreover, implant-supported restorations fabricated using the digital impression technique (Group D) (25.81±4.15) (%) showed a significantly higher loss ratio of removal torque between before and after loading than those constructed using conventional impression technique (Group C) (20.03±2.41) (%) (p<0.001); indicating that the effect of loading was more detrimental on group D restorations when compared to those of group C.

DISCUSSION

Hence the results showed that there was a difference in screw loosening after cyclic loading between digital and conventional impression techniques in the fabrication of implant-supported screw-retained zirconia restorations; the null hypothesis was rejected.

Mechanical factors, such as the fit of the implant-abutment connection and the preload of the abutment screw, play a significant role in implant rehabilitation. Loss of preload during occlusal loading can compromise the stability of the implant-abutment connection, leading to screw loosening and potential fractures.[10] Achieving a passive fit between the prosthetic framework and supporting implants is essential for the long-term success



(A) **(B)**

Figure (5):
(A): Bar chart showing mean and standard deviation values post-load removal torque (Ncm).
(B): Bar chart showing mean and standard deviation values loss ratio of removal torque between before and after loading (%).

Table (1): Statistical difference between conventional implant impression technique and the digital implant impression technique (Shapiro-Wilk's test).

Variable	**Conventional impression (Group C)**	**Digital impression (Group D)**	*P*-Value
	Mean ±SD	Mean ±SD	
Post-load removal torque (Ncm)	22.15±0.77	20.63±0.91	<0.001*
loss ratio of removal torque between before and after loading (%)	20.03±2.41	25.81±4.15	<0.001*

**Statistically Significant at P<0.05.*

of implant-supported prosthetic treatments, significantly reducing mechanical and biological complications.

This necessitates meticulous attention to detail in prosthesis design and alignment to prevent gaps that could harbor harmful microorganisms, thereby safeguarding against complications that could compromise implant integrity and patient health. Therefore, to achieve a passive fit, an accurate impression free from distortion is essential.[11]

In this study a 30 Ncm tightening torque was applied to the implant abutment screws. A specific torque is recommended for every screw in each implant system according to their manufacturers. The application of the optimum torque to the implant-abutment complex is critical to produce a successful implant-supported prosthesis. Retightening the screw should be done after 10 min of initial screw tightening to compensate for the settling effect.[12] The load was applied with a 45-degree angle to simulate intraoral lateral forces. In our study the applied force chosen was 50 N and had a frequency of 1.6 Hz.

In this study, the results showed a statistically significant difference between the removal torque loss ratio after applying cyclic loading between the two groups.

Implant-supported restorations fabricated using conventional impression technique (22.15±0.77) (Ncm) had a significantly higher post-load removal torque than those constructed using digital impression (20.63±0.91) (Ncm).

Moreover, implant supported restorations fabricated using the digital impression technique (Group D) (31.22±3.04) (%) had a significantly higher loss ratio of removal torque after loading than those constructed using the conventional technique (Group C) (26.17±2.58).

These results were in agreement with Ajioka H et al. in 2016,[13] who stated that there was a significant difference in the accuracy in regard to distance and angulation errors as the digital impressions using an intraoral scanner exhibited slightly greater distance and angulation errors than conventional impressions made by conventional silicon impression technique. Also, Basaki K et al. in 2017[14] found that the digital impression method was less accurate in producing definitive casts than the conventional approach.

The results of this study were also in agreement with the results of a study by Mühlemann S et al. in 2018[15] comparing the mean precision of implant position reproduction from conventional and digital impression techniques. The results showed that the conventional implant model represented the greatest reproducibility of the implant position, while digital implant models demonstrated less precision than the conventional workflow.

Yet, Studies of Sang J. Lee et al. in 2022[16] and Fathi A. et al. in 2023[17] found no significant differences between both digital and conventional impression techniques. These controversial results may be explained by the difference in methodology with this study, as Sang J. Lee et al. in 2022[16] used the closed tray impression technique in the conventional method.

CONCLUSIONS

Within the limitations of this study, the results showed that the screw retained suprastructure fabricated from conventional impression technique showed less liability for screw loosening when cyclic loading than those fabricated from digital ones.

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