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A comparative study to evaluate abutment screw loosening with internal hex parallel vs. conical connection abutments at different torque values on cyclic loading - An In-Vitro Study.

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Abstract

The complications of implant-supported prostheses can be classified into mechanical and biological ones, one part of which is associated with screw loosening. This in vitro study was aimed to evaluate abutment screw loosening with internal hex parallel vs. Conical connection abutments at different torque values on cyclic loading.

Materials and Methods: In this study, a total of 60 implants in metal blocks (30 × 20 × 15 mm) were mounted per pendicular to the surface. They were then randomly divided into two groups: Group I – Internal hex parallel connection Subgroup- (torque) GP I a)10 Ncm GP I b) 20 Ncm GP I c) 30 Ncm Group II – Internal hex Conical connection Subgroup – (torque) GP II a) 10 Ncm GP II b) 20 Ncm GP II c) 30 Ncm Each fixture was vertically placed in the center of an metal model. The samples were fixed to the jig, and an implant abutment connected it with a 10, 20, 30 Ncm tightening torque with different connection. The samples were subjected to eccentric cyclic loading (at a distance of 5 mm) away from center of abutment at 100,000 cycles. A torque gauge was used to evaluate screw loosening by measuring RTVs in (Ncm) before and after cyclic loading. The removal torque loss ratio before and after cyclic loading and the removal torque loss ratio between before and after cyclic loading were calculated and analyzed using the SPSS statistical analysis.

Results: The independent sample t test was used to carry out the difference in the values between the samples of osstem conical and a din internal hex parallel with samples subjected to different torque, The values were compared individually with each other by keeping p value <0.05 as statistically significant. Group statistics was carried out between values. By comparing the means between the values, it was observed that an osstem conical connections with30 N-com torque has lesser screw loosening than a din internal hex parallel and this difference on comparing the outcome with regards to screw loosening is statistically significant ($p < 0.05$).

Conclusion: The internal connection has better resistance to screw loosening than external connection and 30 Ncm torque value shows less screw loosening as that compared to 10 and 20 Ncm torque.

Keywords: Implant, abut ment, screw loosening, universal testing machine, torque values, conical cone ction, parallel connection

Introduction

Oral implantology has undergone a well-deserved rebirth or rediscovery and implants are considered the treatment of choice in an increasing number of carefully selected cases.[1]Despite the high medical advancement of implants, there are various problems observed like abutment screw fracture, soft tissue penetration, mucosal imitation then screw loosening. A common problem associated with the prosthetic application of dental implants is the loosening and fracturing of screws in all of the types. That holds the prosthesis to the implant which is induced by way of insufficient tightening torque, settling effect, vibrating micro - movement, excessive bending and fatigue, in appropriate implant position, inadequate occlusal design or crown anatomy, a variant of hex dimension, mild differences in fit and accuracy, tension on abutment and cylinder from ill-fitting restorations, as well as improper screw design[2]

Several researches have been performed together with the intention of accomplishing an accurate and stable connection between the components of implant systems. The connection is accomplished by means of bolts created by the union between the implant and the prosthetic element.[3]

The main challenge in the develop ment of implant-abutment connection design depends on lowering the incidence concerning mechanical problems while improving the soft/ hard tissue and the prosthetic interface.[4]

Several factors related to screw design and fabrication can increase or decrease the risk of abutment or prosthetic screw loosening in a metal-to-metal screw system. [5] Screw loosening may cause implant or screw fracture, in adequate occlusal force distri bution, and possible osseo integration failure.[6-7] It was reported that the main factor in screw loosening was an inappropriate tightening torque. If the tightening torque was not consistent, the following preload showed a difference and could affect the removal torque.[8-9]The process of screw loosening was described in two stages. Initially, external forces cause sliding between the threads, partially relieving the stretching of the screw and reducing preload. The second stage is attained by a gradual reduction of preload below a critical.[10]

When evaluating the screw loosening of new abutment screws and after successive tightening, it was found that the percentage of the initial torque loss is lower when screws that already suffered the application of an initial torque were used, remaining stable after application of successive torques that is why retightening the old screw is a current option.[11]

It was strongly recommended that retightening of implant abutment screw is important to decrease the possible screw loosening.[12-13-14].

During the last decade, dental implants have been constantly evolving through development and research in order to improve the quality of patient care.[15-16]Osseointegration has been considered as a fundamental and priority factor related to the success of the implants.[17]

Screw loosening may cause implant or screw fracture, inadequate occlusal force distribution, and possible Osseo integration failure. In addition, screw loosening would also lead to micro motion at the implant abutment interface during mastication.[13]

The degree of filtration between and implant and its prosthetic components depends on variable factors, such as the geometry of the connection, a precise fit between the components, the rotational freedom of the abutment on the implant, the applied torque load to tighten the abutment, the micro movements between the components of the implant-abut ment complex during function and the abutment materials.

The purpose of this comparative in vitro study is to evaluate abutment screw loosening with internal hex parallel vs. Conical connection abutments at different torque values on cyclic loading.

Materials & Methods

In this study we used Adin dental implant - Internal hex parallel connection (Adin dental implant system), Osstem Dental implant -Internal hex Conical connection (Osstem Co. Seoul, Korea), Adin and osstem Abutment, Adin and Osstem Abutment Adin Abutment screws, Stainless steel models, Metal mounting jig, Dental surveyor (Dental farm. Torino. Italy), Torque gauge (Adin dental implant system, Torque gauge (Osstem Co. Seoul, Korea), Resin cement RelyX^{TM} (3M ESPE U200 self-adhesive resin cement), Adin Hex drive (Adin dental implant system), Osstem Hex drive (Osstem Co. Seoul, Korea),Universal testing machine.

Total number of 6 implants with diameter 5mm in which 3 of internal hex parallel (Adin) and 3 of internal hex conical connection (Osstem) (FIG.1) with 6 abutments respectively were used in this study. A total number of 60 abutment screws were used, 30 for each group. (fig. 2)

Further, a torque of 10Ncm, 20Ncm, 30Ncm was applied on 10 abutment screws respectively. The groups are divided as follows.6 stainless-steel rectangular metal model having dimensions 30mm x 20mm x 15mm were used in this study. A hole was drilled into center of the stainless-steel model as per the diameter of the implant (5mm) where center was determined using dental survey or. Implant was vertically inserted per pendicular to the base of model.

Abutment was fixed to the implant (Fig.3). Abutment screw was first tightened with finger pressure, then a torque gauge was used to ensure accurate application of predetermined torque of 10Ncm, 20Ncm, 30Ncm torque load in each connection group. The abutments was retightened after 10 min with their respective torque. The initial removal torque value was measured using torque gauge and recorded.

A customized rigid metal mounting jig was fabricated to hold the device to ensure solid fixation of the assembly while testing with universal testing machine (fig 4a). After the abutment connection and setting of the metal jig using resin cement, a universal testing machine was used to apply a cyclic load to the specimen (fig 4b). The torque gauge was held firm so that the long axis of the implant with the driver was seated in the screw head and rotated clockwise until the abutment screw had been tightened as recommended by the manufacturer.

Subsequently a universal testing machine was used to apply a cyclic load of 130N perpendicular to the metal tube at a distance 5mm away from the center of abutment for 1,00,000 cycles of eccentric dynamic cyclic loading. The contact time between the rod and the metal tube will be 0.2 s at a rate of 1 Hz which simulates the tooth contact duration of each masticatory cycle. After cyclic loading is done, screw loosening and reverse torque values was measured using same torque gauge. Above mentioned procedure was repeated for all groups and then statistically analyzed.

Results & Discussion: In this study, the results and data analyzed has been presented in the form of tables.

1. Descriptive study details

This study comprised of total 60(n) samples under two groups of Adin – internal hex parallel of Osstem internal hex conical with torque of 10, 20 and 30 N-cm were included as shown in the graph 1 and 2.

A) Adin internal hex Parallel group:

A total of 30 samples were included under Adin- internal hex parallel group. It was subjected to a torque of 10, 20 and 30 N-cm with a sample of 10(n) subjected to each torque **as shown in graph 1.**

B) Osstem internal hex Conical group:

A total of 30 samples were included under Osstem conical group. It was subjected to a torque of 10, 20 and 30 N-cm with a sample of 10(n) subjected to each torque as shown in graph 2.

Test for Data Normality

For testing, whether the data is normally distributed or not, we used both kolmogorov - smirnov test and shapiro - wilk test for checking the normal distribution of data with the p value or the alpha value 0.05 as the standard as shown in table 1. It was seen that the value of both kolmo gorov - smirnov test and shapiro - wilk test is > 0.05, which means that the data is normally distributed over the.

The distribution of the data was also observed for all the given parameters through histograms and normal Q-Q plot. For all the parameters, it was seen that the mid points of histograms as shown in graph 3, for all parameters when joined, forms a linear line of normal distribution with no presence of kurtosis and skewness or no deviation of data to the extremes were evident.

The mean value of the parameters were not shown deviation towards the extreme while the standard deviation values were less, as depicted in Q-Q plot as shown in graph 4, with the data from samples following the line of distribution towards the mean or the expected value did not deviate more from the approximate or the original value.

The error bar as shown in graph 5, for all parameters, did not show more variance towards the extreme as the median value do not show more deviation towards the upper (25th percentile) and lower value (75th percentile)

The results of the study are as follows:

Table 2: Adin-internal hex and Osstem conical parallel at Initial Torque

As shown in table, the t test was used to carry out the difference in the values between the two samples. The values were compared individually with each other by keeping p value <0.05 as statistically significant. Group statistics was carried out between initial torque values. By comparing the means between the values, no significant difference was observed (*p* >0.05).

Table 3: Adin-internal hex and Osstem conical at Initial Untightened Torque

As shown in table, the independent sample t test was used to carry out the difference in between the two samples at initial untightened torque. The values were compared individually with each other by keeping p value <0.05 as statistically significant. Group statistics was carried out between. By comparing the means bet ween the values, no significant difference was observed (p >0.05).

Table 4: Adin-internal hex parallel and Osstem conical after 100000 cycles Untightened Torque

As shown in table, the independent sample t test was used to carry out the difference s in the values in the after 100000 cycles untightened torque. The values were compared individually with each other by keeping *p* value <0.05 as statistically significant. Group statistics was carried out between values. By comparing the means between the values, it was observed that a conical connections with 30 N- com torque has lesser screw loosening than a din internal hex parallel and this difference on comparing the outcome with regards to screw loosening is statistically significant (*p* <0.05).

Table 5: Subgroup comparison between Adin internal hex parallel and Osstem conical with regards to the samples subjected to torque of 10 N-cm

As shown in table, the independent sample t test was used to carry out the difference in the values between the samples of osstem conical and a din internal hex parallel with samples subjected to torque of 10 N-cm. The values were compared individually with each other by keeping p value <0.05 as statistically significant. Group statistics was carried out between values. By comparing the means between the values, it was observed that osstem conical connections with 10 N-com torque has lesser screw loosening than ad in internal hex parallel and this difference on comparing the outcome with regards to screw loosening is statistically not significant (*p* >0.05).

Table 6: comparison between Adin internal hex parallel and Osstem conical with regards to the samples subjected to torque of 20 N-cm

As shown in table, the independent sample t test was used to carry out the difference in the values between the samples of osstem conical and ad in internal hex parallel with samples subjected to torque of 20 N-cm. The values were compared individually with each other by keeping *p* value <0.05 as statistically significant. Group statistics was carried out between values. By comparing the means between the values, it was observed that an osstem conical connections with20 N-com torque has lesser screw loosening than ad in internal hex parallel and this difference on comparing the outcome with regards to screw loosening is statistically significant (*p* <0.05).

Table 7: Subgroup comparison between Adin internal hex parallel and Osstem conical with regards to the samples subjected to torque of 30 N-cm

As shown in above table, the independent sample t test was used to carry out the difference in the values between the samples of osstem conical and ad in internal hex parallel with samples subjected to torque of 30 N-cm. The values were compared individually with each other by keeping p value <0.05 as statistically significant. Group statistics was carried out between values. By comparing the means between the values, it was observed that an osstem conical connections with30 N-com torque has lesser screw loosening than Adin internal hex parallel and this difference on comparing the outcome with regards to screw loosening is statistically significant (p <0.05).

Figures & Tables

Figure 1: Adin dental implant &Abutment and Osstem dental implant & abutment

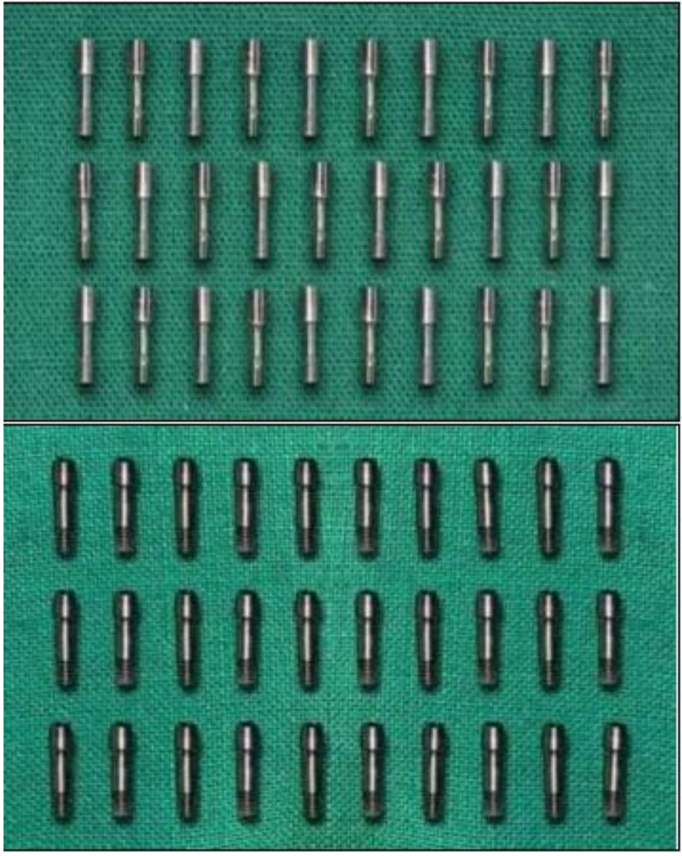


Figure 2: Adin abutment screw and osstem abutment screw

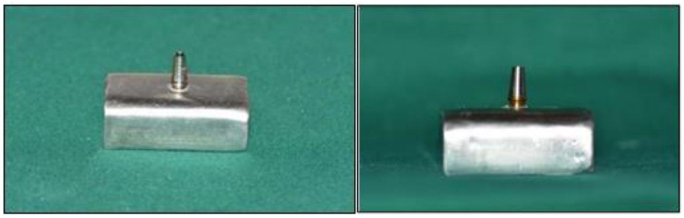


Figure 3: metal model with implant and abutment (Adin parallel connection and osstem conical connection)

Figure 4: a) metal mounting jig fabricated on abutments b) cyclic loading

Table 1: Nature of data distribution.

	Kolmogorov-smirnov test			Shapiro-wilk test		
	statistics	df	Sig.	statistics	df	Sig.
Adin internal hex parallel at 10 N-cm	.07	1	.001	.887	1	.06
Adin internal hex parallel at 20 N-cm	.12	1	.113	.909	1	.05
Adin internal hex parallel at 30 N-cm	.08	1	.169	.920	1	.061
Osstem conical at 10 N-cm	.05	1	.078	.934	1	.080
Osstem conical at 20 N-cm	08	1	052	211	1	07
Osstem conical at 30 N-cm	12	1	077	310	1	05

Table 2: Adin-internal hex and Osstem conical parallel at Initial Torque

Group Statistics

	Sample	N	Mean	Std. Deviation	Std. Error Mean
Value	Adin internal hex parallel	30	20.0000	10.00000	5.77350
	Osstem conical	30	20.0000	10.00000	5.77350

Table 3: Adin-internal hex and Osstem conical at Initial removal Torque

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.000	1.000	.000	4	1.000	.00000	8.16497	-22.66958	22.66958
Value Equal variances not assumed			.000	4.000	1.000	.00000	8.16497	-22.66958	22.66958

Group Statistics

	Sample	N	Mean	Std. Deviation	Std. Error Mean
	Adin				
	internal				
	hex parallel	30	15.3333	7.50555	4.33333
Value					
	Osstem conical	30	14.0000	8.00000	4.61880

Table 4: Adin-internal hex parallel and Osstem conical after 100000 cycles removal Torque value

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances									
	.004	.954	.211	4	.844	1.33333	6.33333	-16.25082	18.91749
assumed									
Value Equal variances not									
			.211	3.984	.844	1.33333	6.33333	-16.27900	18.94567
assumed									

Group Statistics

	Sample	N	Mean	Std. Deviation	Std. Error Mean
	Adin				
	internal				
	hex parallel	30	12.3333	5.50757	3.17980
Value					
	Osstem				
	conical	30	11.0000	6.00000	3.46410

Table 5: Subgroup comparison between Adin internal hex parallel and Osstem conical with regards to the samples subjected to torque of 10 N-c

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference

								Lower	Upper
Equal variances									
	.007	.037	.284	4	.031	1.33333	4.70225	-11.72219	14.38886
assumed									
Value Equal variances not									
			.284	3.971	.040	1.33333	4.70225	-11.75985	14.42652
assumed									

Group Statistics

	sample	N	Mean	Std. Deviation	Std. Error Mean
Adin					
Internal hex		10	7.50	.70	.50000
Parallel					
Osstem conical		10	5.50	.70	.50000

Table 6: Comparison between Adin internal hex parallel and Osstem conical with regards to the samples subjected to torque of 20 N-cm

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed value	.	0.08	2.828	2	.106	2.00000	.70711	-1.04243	5.04243
Equal variances not assumed			2.828	2.000	.106	2.00000	.70711	-1.04243	5.04243

Group Statistics

	sample	N	Mean	Std. Deviation	Std. Error Mean
Adin internal hex parallel		10	12.50	2.12	1.50
Osstem conical		10	13.50	2.12	1.50

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the

								Difference	
								Lower	Upper
Equal variances assumed		0.04	.471	2	.684	1.00	2.12	-8.12	10.12
Value Equal variances not. assumed			.471	2.000	.684	1.00	2.12	-8.12	10.12

Table 7: Subgroup comparison between Adin internal hex parallel and Osstemconical with regards to the samples subjected to torque of 30 N-cm

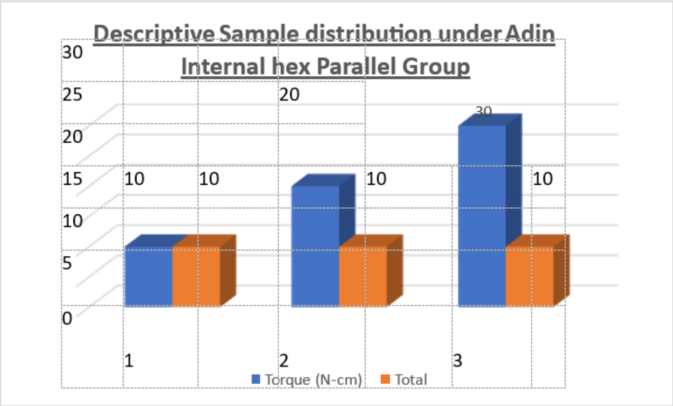
Group Statistics

	sample	N	Mean	Std. Deviation	Std. Error Mean
Adin internal hex parallel		10	20.50	3.53	2.500
Osstem conical		10	19.50	3.53	2.500

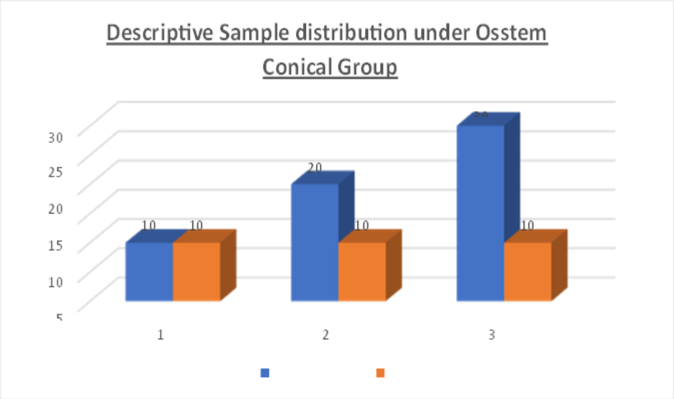
	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed		0.03	.283	2	.804	1.00	3.53	-14.21	16.21
Value Equal variances not. assumed			.283	2.000	.804	1.00	3.53	-14.21	16.21

Graph

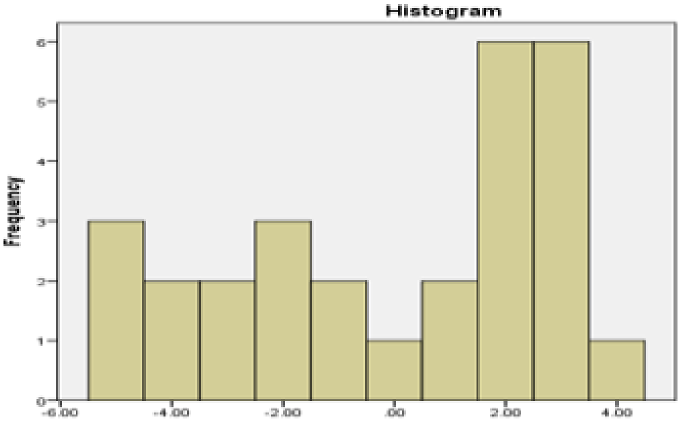
Graph 1: Sample distribution under Adin internal hex parallel connection group



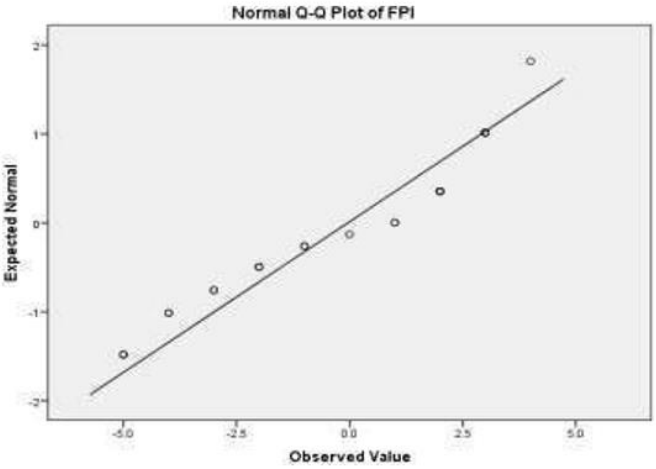
Graph 2: Sample distribution under Osstem conical connection group



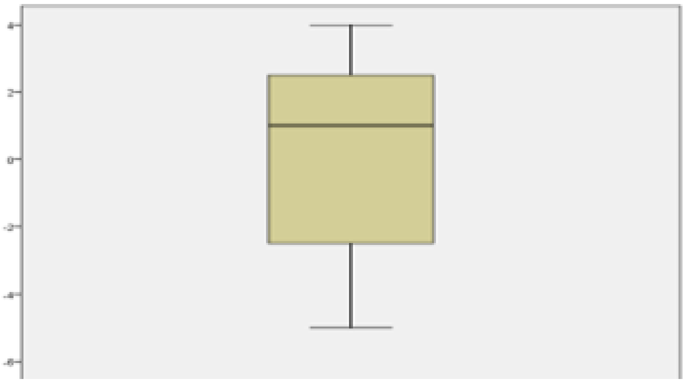
Graph 3: Data normality through histogram



Graph 4: Data normality through Q-Q plot



Graph 5: Data normality through Error bar diagram



Disscussion

A common problem associated with the prosthetic application of dental implants is loosening and fracturing of screws that hold the prosthesis to the implant which is induced by way of insufficient tightening torque, settling effect, vibrating micro- movement, excessive bending and fatigue, inappropriate implant position, inadequate occlusal design or crown anatomy, variant of hex dimension, mild differences in fit and accuracy, tension on abutment and cylinder from ill-fitting restorations, as well as improper screw design.[5]

Several factors related to screw design and fabrication can increase or decrease therisk of abutment or prosthetic screw loosening in a metal-to-metal screw system. These primarily are related to preload.[6] In addition, factors that affect abutment screws also include component fit, hex height (or depth), and platform diameter. A flat-head screw is preferred for prosthetic screws. A flat-head screw distributes forces more evenly within the threads and the head of the screw and is less likely to distort a nonpassive casting. As a result, the dentist can more easily identify thenonpassive casting.[7]

A key objective of this study was to aware clinicians how implant connections andtorque values can affect on screw loosening. So every step from the selection of proper implant connection to the procedure plays important role in the success ofa dental implants.

In this study 10, 20 and 30 Ncm tightening torque was applied to the abutment screws on different implant systems, respectively. Specific torque is recommendedfor each screw for different implant systems according to their manufacturers, respectively.

To simulate intraoral lateral forces, the load was applied eccentrically 5mm away from the Center of the abutment. A number of studies have investigated the influences of eccentric loading by using fatigue tests and dynamic cyclic loading to simulate masticatory forces. The influence of lateral cyclic loading on abutmentscrew loosening in an external hexagon implant system was investigated by Khraisat et al. They found that reverse torque values were better preserved undereccentric lateral than under centric lateral loading.

Chewing forces of adult individuals with natural dentition and those with prosthetic rehabilitation are between 50 N and 2440 N, showing a decreasing pattern from molars to incisors. In our study, the applied force chosen is 130 N and1hz frequency was applied for the simulation of more actual clinical situations, the frequency of cycles is reported in the literature as ranging from 1 to 19 Hz . It was clarified that in a day, an individual typically performs three episodes of chewing lasting 15min, with a frequency of 60 cycles per minute (1 Hz); this generates 2700 chewing cycles per day so 100,000 cycles correspond to around one month.

In this study, the results showed that there is a significant difference in the removaltorque loss ratio before and after application of dynamic cyclic loading for two different connection designs and with different torque values. The conical connection had the lowest percentage of initial and post load removal torque loss compared to parallel connection and 30n cm torque had low percentage of torque loss than 10 Ncm torque. According to results of this current study, percentage of removal torque loss is significant difference between two implant systems which conical connection shows decreased percentage of removal torque value than parallel connection of implant system.

The results from this study were agreed by S.R. Sammour et al. Who stated conical implant abutment connection designs provide more biomechanically suitable prosthetic options than other designs.

Conclusion

Screw loosening is one of the most common mechanical complications of implant-supported restoration. Knowing the causes and relevant factors can help clinicians make better choices in clinical practice. Within the limitations of the study, the following conclusions can be made:

1. The internal connection has better resistance to screw loosening thanexternal connection.
2. The geometrical morphology of the abutment implant interface affects the stability of the implant abutment connection.
3. Conical connection design is preferred over parallel connection design.
4. 30 Ncm torque value shows less screw loosening as that compared to 10 and20 Ncm torque.

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Legend Tables

Table 1: Readings for Adin internal hex parallel connection for 10 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
10	16	13
10	17	14
10	18	15
10	11	8
10	18	15
10	14	18
10	15	15
10	11	9
10	30	25
10	22	19

Table 2: Readings for Adin internal hex parallel con nection for 20 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
20	16	11
20	17	12
20	18	13
20	11	6
20	18	13
20	21	19
20	18	13
20	12	7
20	30	25
20	22	17

Table 3: Readings for Adin internal hex parallel connection for 30 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
30	16	15
30	17	16

30	18	16
30	11	10
30	18	17
30	24	13
30	18	14
30	12	10
30	30	29
30	22	21

Table 4: Readings for Osstem Conical connection for 10 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
10	14	19
10	15	13
10	11	9
10	30	26
10	24	19
10	18	16
10	17	14
10	18	13
10	11	8
10	18	15

Table 5: Readings for Osstem Conical connection for 20 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
20	23	13
20	19	14
20	12	10
20	30	29
20	23	21
20	17	15
20	17	16
20	18	16
20	11	10
20	18	17

Table 6: Readings for Osstem Conical connection for 30 torque

Initial Torque	Initial removal Torque	After 100000cycles removal torque
30	26	22
30	20	19
30	15	13
30	31	29
30	22	21
30	16	15
30	17	12
30	18	13
30	11	9
30	18	15