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The difference of removal force values on various preload application on 5º taper implant transfer abutment to determine the optimal preload

Samuel Manuela Nurhadi [1], Adelisa Devita Ryani [1,*], Harly Prabowo [2], Agus Dahlan [2], Nadia Kartikasari [2] and Alief Wikarta [3]

[1] *Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia.*
[2] *Department of Prosthodontics, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia.*
[3] *Department of Mechanical Engineering, Institute Teknologi Sepuluh Nopember, Surabaya, Indonesia.*

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Abstract

Background: Dental implants successfully become long-term solution in Indonesia with the two-piece variety being prevalent. The 5º tapered internal connections are favored for their stability compared to external connections. Preload is essential for stability relying on friction between the implant-abutment connection.

Purpose: Evaluate the differences in removal force value resulting from various preload applications on 5º taper implant transfer abutment to determine the optimal preload.

Methods: Implant abutments with 5º taper implant transfer abutments were evaluated in the study. The control group of this study derived from the manufacturer's preload recommendation of 35 Ncm. Preloads from 10 Ncm, 15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, 40 Ncm, 45 Ncm, 50 Ncm were used as independent variables in this experiment (n=3). The abutment screw was removed before the tensile test using a universal testing machine (UTM). Statistical data analysis was conducted using the One-way ANOVA and Tukey HSD (p<0,05).

Results: The 35 Ncm preload has the highest result with a mean value of (723 N ± 53.8). The 10 Ncm preload had the lowest results with a mean value of (267 N ± 71.4). There was no remarkable difference between the 30 Ncm and the 35 Ncm preload groups.

Conclusion: There is a difference in removal force values at various preloads given. The removal force value at 35 Ncm is the optimal preload recommended by the manufacturer in line with a preload of 30 Ncm which is not significantly different from 35 Ncm.

Keywords: Dental Implant; Preload; Morse Taper Internal Connection; Removal Force.

1. Introduction

Dental implant is a medical device that is implanted to the jawbone [1]. The material used in dental implants is mostly titanium. Titanium dental implant is well known as a highly reliable long-term treatment option for replacing missing teeth with a success rate from 92,8% to 95% over a 10-year period [2].

The endosseous dental implant is commonly used which is inserted to replace the tooth root. Depending on the system preferred, the abutment of the dental implant is attached to the implant by a separate screw (transfer abutment), or it can be attached directly to the abutment body itself by a threads mechanism (solid/cemented abutment) [3].

* Corresponding author: Adelisa Devita Ryani

The transfer abutment has two connection types, including the external connection (EC) abutment and the internal connection (IC) abutment. The external connection was the first connection utilized in modern implant technology by Branemark. The advantages of EC cover the insertion of a prosthesis, allowing removal of the prosthesis, and providing an anti-rotation mechanism. The disadvantages of EC include the fact that it fails to avoid the establishment of micro-gaps, which can lead to complications due to high occlusal loads and allow for micromovement within the implant and the abutment. The IC connection leads to better connection, including the increases in the expansion of the implant's and abutment's contact area, enables load dissipation, and improves stability. The IC is divided into internal hexagons, internal octagons, and taper connections [4,5].

The taper connection is the internal connection that shows a cone shape at the implant-abutment connection. The taper internal connection has a great mechanical retention for connectors. It is characterized by a high contact pressure and resistance to friction between the internal implant surface and abutment. This mechanism is aimed to minimize the abutment screw loosening and to improve mechanical stability. The taper connection facilitates the majority of the load transfer from the abutment to the implant [6].

The implant-abutment angle of the morse taper internal connection has various angles ranging from 1º to 12º. This ranging degree of taper on the inner surface of the implant abutment connection is another important factor in connection stability. When the degree of the taper is increased, the rate of implant fracture decreases, but the connection becomes unstable and vice versa. The morse taper conical connection with a taper angle smaller than 5,8º ensures a secure and stable connection between the implant and abutment. In the market of dental implants, there are manufacturers that provide a morse taper internal connection with 5º of inclination where the 5º morse taper internal connection provides stability [7,8].

This study focused on evaluating the optimal preload that should be applied to 5º implant transfer abutment. The preload recommended for 5º implant transfer abutment by the manufacturer is 35 Ncm. However, the higher the number of preloads, the higher frictional retention. Higher frictional retention is related to the cold welding phenomenon. The connection will occur in intimate contact between the outer and inner walls of the abutment, resulting in stability between the implant and the abutment. The axial loading, such as preload between the insertion and removal force in the connection will have distribution forces based on the taper angle, the length of contact area, the internal and external diameter of the abutments, the depth of insertion of the abutment, the properties of the material, and the coefficient of friction of the contact surface. Lower preloads result in poorer stability, as opposed to higher preloads which result in better stability. Therefore, giving a larger preload should produce better stability in the 5º taper implant transfer abutment relationship [9].

2. Material and methods

The implants used are Anyridge® (MegaGen, Implant, Daegu, South Korea) with implant length of 7 mm, implant diameter of 5mm, abutment diameter profile of 6 mm, cuff height of 3 mm, and post height of 5,5 mm. The implant transfer abutments are prepared to be given preload of 10 Ncm, 15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, 35 Ncm, 40 Ncm, 45 Ncm and 50 Ncm using torque devices Surgical XT by NSK (NSK LTD, Fujisawa, Japan), contra-angle handpiece Ti-Max X-SG20L Ratio 20:1 by NSK (NSK LTD, Fujisawa, Japan), and 1.2 hex low-speed screwdriver. After the given preload by every preload group (n=3), the abutment screw is released while the transfer abutment itself remains in the implant.

Removal force values are measured using Universal Testing Machine (UTM) ST-1001 (SALT, Incheon, South Korea). The UTM comes with two grips, the upper grip part clamping the transfer abutment and the lower grip part clamping the implant, while the implant and transfer abutment have become a single entity with the abutment screw that had already been removed. The crosshead speed of the UTM has been set at a speed of 2 mm/minute. The specimens that already received a preload were tested using the tensile test with the output result of removal force in Newton.

3. Results

The study with 9 experimental groups was conducted with each group consisting of 3 implant-abutment samples with a 5° taper. Various preloads given are 10 Ncm, 15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, 40 Ncm, 45 Ncm and 50 Ncm. The following are the results of the removal force from the tensile test on the implant-abutment connection with a 5° taper.

Table 1 Data Results of Implant Removal Force Value from Various Preload Applications

Data		Preload (Ncm)								
		10	15	20	25	30	35	40	45	50
Removal force value (Newton)	1	234	401	538	535	678	744	385	457	474
	2	218	310	401	557	699	704	438	491	502
	3	349	276	522	615	780	721	503	501	497
Average		267	329	487	569	719	723	442	483	491
Standard Deviation		71.4	64.6	74.9	41.3	53.8	20	59.1	23	14.9

The data obtained from 27 samples of all groups was statistically processed using IBS SPSS 23. The study was statistically evaluated using one way ANOVA test to analyze the mean difference of data from more than two groups which in this study had 9 groups. The analysis continued using post hoc which was Tukey's HSD to evaluate whether the average removal force value was significant in the amount of variance analysis.

The validity of the data was assumed that the nine populations are mutually independent which is normally distributed with a small sample. The assumption of variance of the two populations can be assumed to be the same (homogeneous) or different (heterogeneous). The data was initially tested using the normality test to evaluate whether the data is normally distributed and the homogeneity of variance test to evaluate whether the data of the variation in the removal force values of the nine groups being compared are equal or homogeneous.

The normality test performed with the Shapiro-Wilk test showed a significance value of ($p>0.05$) with p = 0.214 in group 10 Ncm, p= 0.508 in group 15 Ncm, p = 0.204 in group 20 Ncm, p = 0.515 in group 25 Ncm, p = 0.375 in group 30 Ncm, p = 0.835 in group 35 Ncm, p = 0.888 in group 40 Ncm, Sig. = 0.417 in group 45 Ncm and Sig. = 0.321 in group 50 Ncm. It can be concluded with the normality test that the samples in the 10 Ncm, 15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, 35 Ncm, 40 Ncm, 45 Ncm and 50 Ncm are normally distributed. The Levene of homogeneity test results showed a significance value of p = 0,094 ($p>0.05$). This shows that the data variance is homogeneous. Because the data in both groups are normally distributed and homogeneous, a one-way ANOVA statistical test can be carried out.

Table 2 One-way ANOVA Results Shows a Significant Differences Between

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	569618.667	8	71202.333	26.530	0.000
Within Groups	48310.000	18	2683.889		
Total	617928.667	26			

The ANOVA test was conducted to see if there was a difference between the data groups as a whole. It can be seen through the table of One-way ANOVA results. The ANOVA test results showed a significance value of p=0.000 ($p<0.05$), which means there is a significant difference between groups.

Followed by a Post Hoc test using Tukey's HSD test to see differences in treatment groups. It can be seen in Table 5.4. The p-value is considered a difference if $p<0.05$. The results of data analysis showed a significant difference in most of the between groups $p<0.05$ and no significant difference $p>0.05$. The interpretation of Tukey's HSD test result can be seen in Figure 1 which has the same lowercase information indicating similarity in terms of average values between groups.

Table 3 Test between preload groups that have significant differences using Tukey

Preload	10 Ncm	15 Ncm	20 Ncm	25 Ncm	30 Ncm	35 Ncm	40 Ncm	45 Ncm	50 Ncm
10 Ncm	-	0,857	0,002*	0,000*	0,000*	0,000*	0,014*	0,002	0,001*
15 Ncm		-	0,032*	0,001*	0,000*	0,000*	0,225	0,038	0,026*
20 Ncm			-	0,599	0,001*	0,001*	0,973	1,000	1,000
25 Ncm				-	0,046*	0,038*	0,128	0,656	0,656
30 Ncm					-	1,000	0,000*	0,001*	0,001*
35 Ncm						-	0,000*	0,001*	0,001*
40 Ncm							-	0.984	0,956
45 Ncm								-	1,000
50 Ncm									-

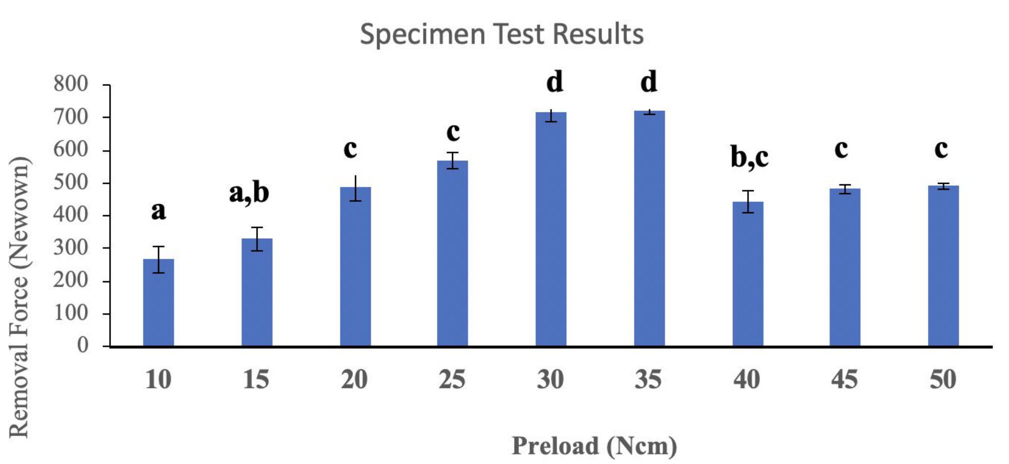

Figure 1 Comparison chart between treatment groups. Different letters indicated the statistically significant difference between groups (P<0,05; Tukey's honestly significant difference (HSD) test

4. Discussion

The biomechanics connection occurs on the two-piece implant, including the external hex connection and the internal friction connection. In this study, the researchers will focus on the internal friction connection. The internal friction connection is connected by friction between the inner inclined plane of the implant and the outer inclined plane of the abutment. The friction biomechanics at the implant-abutment interface show that friction is one of the factors in the stability of the implant-abutment connection to a great extent, depending on the contacting area between the two frictional surface and the tapered angles of the inclined planes to the long axis of the implant. Some types of dental implant systems use internal friction connections to keep the implant and abutment securely connected. Even though the screw abutment may become a bit loose over the preload of screw tightening, the friction between the surfaces takes part in its stability. Despite the screw abutment loosening, the friction helps to maintain a solid connection between the implant and the abutment [10].

The implant diameter that is used in this study is specifically described as 7 mm implant length, 5 mm implant diameter, 6 abutment diameter profile, 3 mm abutment cuff height, and 5,5 mm abutment post height. This specific implant is the implant that is commonly used by dentists in Indonesia. With a 5º taper internal connection, it serves as a connection that is better in terms of stability than the larger angle [**Error! Reference source not found.**,**Error! Reference source not found.**].

Mechanical complications could be happened in implant-supported prostheses, including implant-related in terms of implant fracture, connection related in terms of a screw loosening not only in the prosthesis, but also in abutment, screw fracture, and abutment fracture, and supra fracture related in terms of metal framework fracture in overdenture [10]. The connection-related mechanical complication will be discussed in more detail.

In the process of insertion of the abutment, elastic deformation occurs followed by plastic deformation. The plastic deformation increases the extraction force of the abutment consequences of the insertion force. The distribution forces from the abutment depend on the taper angle, the length of the contact area, the internal and external diameters of the abutments, the properties of the material, and the coefficient of friction of the contact surface [9].

The internal friction connection or conical connection or morse tapper connection is a two-piece dental implant that is connected by an abutment screw. The relation between the implant abutment that is press-fit together with significant friction existing between the two components results in cold welding. The compressive force such as the preload given may cause deeper settling of the abutment into the implant body of conical connections resulting in minimizing the micro-gap and allowing the two-piece system to behave as one piece. This connection also forms a hermetic seal that prevents microbial invasion and anti-rotation through the cold-welded friction fit. It has a high resistance to bending and rotational torque because of the capability to press fit, which reduces the possibility of screw loosening or screw fracture as compared to other connections [11].

After given preload, the abutment screw is removed and the abutment is still attached to the implant. The dislodging of the abutment from the implant required a tensile test. This phenomenon could happen because the friction at the implant-abutment interface is a major determinant of the connection stability and the abutment screw acts as a supportive role to the abutment retention in the Morse taper system. From the clinical perspective, the frictional force caused by the micromotion of the abutments after cyclic loading makes it difficult to remove the abutment from the implant when it is necessary [12].

From these results, the preload groups of 10 Ncm, 15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm are preload groups below the manufacturer's recommendations and the preload groups of 40 Ncm, 45 Ncm, and 50 Ncm are preload groups above the manufacturer's recommendations. The average removal force value in the 10 Ncm group is the lowest among the other groups. The 10 Ncm and 15 Ncm preload groups are below the manufacturer's recommendation. It was found that the 10 Ncm and 15 Ncm preload groups did not have significant differences in the mean values of the removal force. Therefore, system failure can occur in both the 10 Ncm preload group and the 15 Ncm preload group.

In the 20 Ncm and 25 Ncm groups, the average removal force value increased or was significantly different from the 20 Ncm and 25 Ncm preload groups. This is because as the amount of axial displacement, such as the preload increases, the contact of the interface becomes more intimate resulting in increasing tensile removal force and decreasing removal torque due to the loss of tension of the screw-abutment and the threat interface. The removal force value increases, but the 20 Ncm and 25 Ncm groups are preload groups that are less than the manufacturer's recommendations. Therefore, it is possible for system failure to occur [5,12].

The preload groups below the manufacturer’s recommendation result in an increasing mean of removal force. The results show that since 10 Ncm, the connections can have intimate contact between the inner wall of the implant and the outer wall of the abutment. This result is related to the study conducted by Zielak in 2011 with removal force values ranging from 111 Ncm to 295 Ncm, the value resulting in intimate contact between the external wall of abutment and the internal wall of the implant. This is proven by the fact that after a preload is applied, the implant and abutment connection only can be removed after a tensile test [9,13].

The groups of 30 Ncm and 35 Ncm showed no significant result between groups. The 35 Ncm preload is the factory recommendation for the Anyridge® implant by Megagen. It has been found that the 35 Ncm has the highest removal force mean value. The 30 Ncm group is not significantly different from the 35 Ncm group, so it is as optimal as the factory recommendation preload. The preload of 30 Ncm has the same capabilities as the 35 Ncm which can be used to reduce the possibility of the occurring defect. From the perspective of removal force, the use of preload group applications of 30 Ncm with 35 Ncm is clinically equivalent

The researchers found that the preload group started from 40 Ncm had a significant decrease from the 30 Ncm preload groups. This phenomenon might happen in engineering which the change in friction is essentially unpredictable. It is equally likely to be higher or lower than the mean value. When tightening a screw or giving the preload, less than 10% of the force applied makes the screw tighter, and more than 90% is lost due to friction. Considering this event, even slight differences in friction, caused by small variations in the material's structure or unseen manufacturing defects, could be the reason of decreasing in the tensile removal force [14].

The groups of 40 Ncm, 45 Ncm, and 50 Ncm have no significant difference in the mean of removal force values. This is related to the Bozkaya and Müftü study covering that an elastic strain increases the removal force due to a higher interference value. The time when the material exceeds the elastic limit, it will lead to plastic deformation [15]. The plastic deformation leads to a decrease in interference values resulting in lower friction [16]. Furthermore, it will lower the required of the removal force. This could be why in group 40 Ncm, 45 Ncm, and 50 Ncm the mean removal force value decreased significantly from group 35 Ncm.

5. Conclusion

This research concludes that there are differences in the removal force values on the application of various preload values on the 5° taper implant abutment transfer. It was found that the 30 Ncm and 35 Ncm groups have the same average removal force value which is the optimal preload.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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