EVALUATION OF THE EXTERNAL HEXAGON DENTAL IMPLANTS AFTER SIMULATING SURGICAL PLACEMENT AND THE ROTATIONAL FREEDOM OF IMPLANT COMPONENTS

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Abstract. *Currently, there are several possibilities of abutments connections in dental implants. The most common design in use is the external hexagon connection, which, besides the function of transmitting torque at surgical placement, also works as an antirotational mechanism and orientation of the abutment for single tooth prostheses. Several researchers have suggested that screw joint stability is directly correlated with rotational freedom between implant and abutment. This work aimed at evaluating rotational freedom and integrity of two types of implants (Neodent Implante Osteointegrável): a conventional external hexagon implant (EH) and a new implant system called internal torque (IT). In this system, the implant is inserted by means of internal torque, without the need of a mount. A device was designed and made to measure rotational freedom angles of the two systems, after different torque applications. Parallel, rotational freedom values were determined by an analytical model. These values were compared with the experimental results. There have been verified different behaviors between the implants analyzed in relation of rotational freedom for different torque applications. Furthermore, the external hexagon (EH) deformed after 80 Newton cm torque, differently from the internal torque (IT), showing that clinical placement of IT implants does not influence the integrity of implant–abutment interface.*

Keywords**:** *Biomechanics, dental implants, external hexagon implant, torque, rotational freedom.*

1. Introduction

Over the last few decades, the use of dental implants in partially edentulous patients and in single tooth replacements has increased. Brånemark *et al.* (1977) reported the principles of osseointegration of titanium implants in bone tissue and its clinical application in rehabilitation of the edentulous patients, and consequently reestablishment of masticatory function. The results obtained during 10 years of clinical rehabilitation were of a great importance for the recognition of the technique, offering predictability and longevity for the treatment.

The initial proposal of external hexagon implants was transmit torque at surgical placement, and afterwards also worked as an antirotational mechanism and orientation of the abutment for single tooth prostheses. Although these implants had been the most common used and designed by several companies all over the world, possible fatigue or overload failures can occur. Since then, some of the most biomechanical complications reported are loosening or fracturing of the abutments and the prostheses screws (Adell *et al.*, 1981).

Therefore, the external hexagon connection continues to be comprehensively studied with the aim of improving the dimensional machining tolerances of their components (Schulte, 1994), and thus made this screwed joint more stable. The maintenance of the prosthesis stability is considered a function of the preload stress achieved in the abutment screw, which depends on the mechanical properties of the screw, and of the rotational freedom angles between abutment and implant (Binon and McHugh, 1996).

Binon (1995) suggested that the precision of fit between hexagons of abutment and implant should permit less than 5 degrees of rotational freedom to sustain the screw joint stability. Or how much larger is the difference between the dimension of the abutment and the implant, the greater the possibility of the system rotation and loosening or fracturing of the abutment screws.

Currently, some configurations of internal connections of implants have appeared in the market that are able to receive higher torques during the surgical placement and have an effective screw joint stability (Merz, Hunenbart and Belser, 2000). However, sometimes these internal geometries become more difficult in the prosthetic procedure and diminish the number of compatible implant systems. The development of a system that becomes possible the use of internal torque during the surgical placement and of an external hexagon device for the prosthesis construction could optimize the clinical results. However, an implant with both devices would have thinner walls being able to be more susceptible to the deformation of the hexagon, which would make it difficult for prosthesis construction. The use of more resistant materials could solve this problem.

The aim of this work was to evaluate the integrity and the rotational freedom of two types of implants: a conventional external hexagon implant (EH) and a new implant system with internal and external hexagons (IT) developed by the company Neodent Implante Osteointegrável. The analyses had been made analytically, by means of geometric measurements, and by an experimental device.

2. External hexagon dental implants

Dental implants are an important alternative of treatment in the absence of the natural dental element, having a advantage in the preservation of adjacent teeth and the easiness of hygienic cleaning. The used surgical technique for the insertion of the implants is one of the factors that influence osseointegration and is determinative in the necessary time for prosthesis placement. The immediate load technique has been widely used in the cases where the implants reach an excellent primary stability in the bone, being possible the prosthesis placement immediate to the surgery. In these cases the torque transmitted to the implant is higher and therefore they have been used for implants with internal connections. The fragility of the external hexagon of some systems has been a factor in reduction of its clinical use, due to use of the implant mount connected to the external hexagon and the possible deformation of the vertex, compromising the future prosthesis.

However, the dental implants with external hexagon have greater amount of components to solve existing aesthetic and mechanical limitations (Neves et al., 2000a; Neves et al., 2000b). Therefore, the development of the internal torque implant (IT) could be the solution for the insertion of implants where it has the necessity of higher resistance to the torque applied during the surgery without compromising the integrity of the external hexagon, keeping the longevity of prosthesis. With the experimental and theoretical evaluation of this work, comparisons between the systems of implants EH and IT will be made.

(a)

(b)

Figure 1. EH (a) and IT (b) implants

3. Experimental device

For the accomplishment of this work 10 implants with external hexagon (Titamax Pores with mount; 3.75 x 11 mm) and 10 internal torque implants (Cortical Titamax IT; 3.75 x 13 mm) were used, supplied by the company Neodent Implante Osteointegrável (Curitiba, Brazil), as shown in Fig. 2.

Figure 2. External hexagon implants – EH and IT

An experimental device was designed and made to measure rotational freedom angles between the abutment and the implant. It had a set for the insertion of the implant, graduated scale with precision of 0.025°, rod for the rotational angle measurement and a steel device fitted to the abutment, as shown in Fig. 3.

The graduated scale had a system that allowed its movement on the table of the device to coincide to the zero of the scale with the initial point of the angle measurement. This initial point was marked when one of the vertex of the implant hexagon touched one of the sides of the abutment hexagon.

The rod was machined and adapted in a steel device, which interlocked under pressure to the abutment, which served as a reference for the rotational angle measurement. Two abutments, being one for each group of implant, had been used.

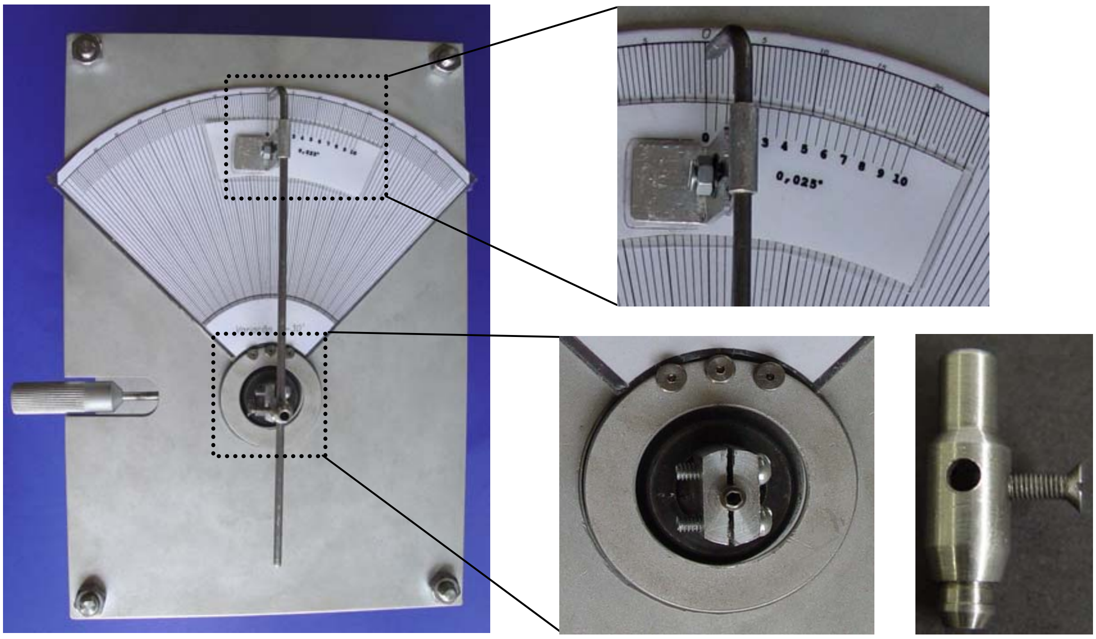


Figure 3. Experimental device used to measure the rotational angle.

3.1. Reading of the rotational freedom angles

In implantology, the insertion of dental implants is made by means of external or internal connections applying a certain level of torque. At this moment, the possibility of an increase in the rotational freedom exists that could lead up to biomechanical complications over time. To simulate this effect of surgical placement, the implants were submitted to three levels of torques: 45 N cm, 60 N cm and 80 N cm.

Initially, the reading of the rotational freedom angles were made with the implants simply located in the device with null external torque. Each implant was placed in the experimental device and connected to the steel device that contains the abutment and the rod, without the need for the abutment screw.

The reading of the rotational angle was made defining an initial point of reference. This point was arrived at by turning the rod by hand in the counterclockwise direction until it had a light resistance of the connection. In this position the graduated scale was adjusted to level zero. In the sequence, the rod was moved in the clockwise direction until, again, a light resistance of the connection occurred. At this moment, the values of the angles read in the scale were registered. Each reading was repeated four times and the mean average was obtained, in order to minimize the errors in the measurements. Figure 4 shows one of these accomplished readings.

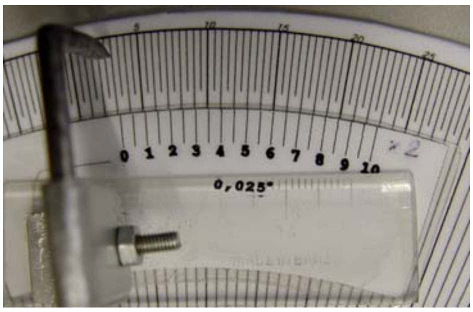
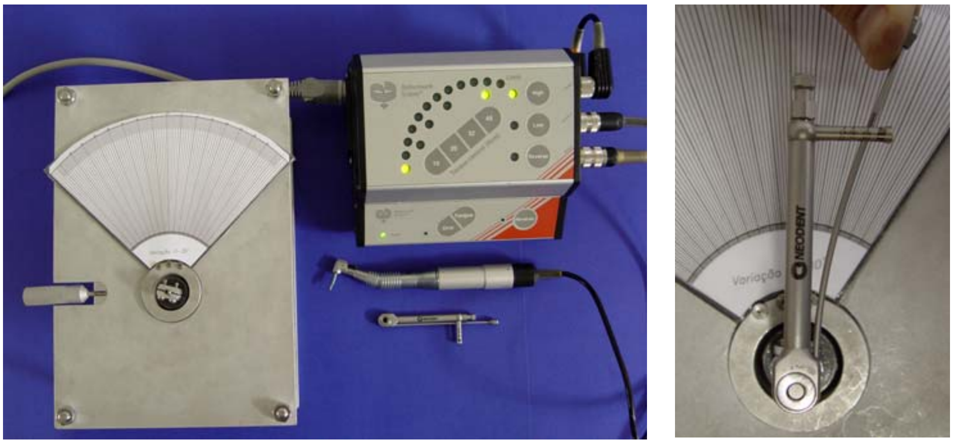


Figure 4. Reading of the rotational freedom angle.

In the sequence the analyzed groups had been submitted to the torques of simulation of surgical placement. Initially, a torque of 45 N cm was applied in the groups, with the aid of the handpiece of the electronic torque controller (DEA 020, Brånemark System, Nobelpharma) in low-speed rotation, as shown in the Fig. 5a. The values of the angles of rotational freedom had been taken of similar manner to the previous case. After, this same analysis was made, successively, for the torque of 60 N cm and 80 N cm, with the aid of a surgical torquemeter ratchet (Neodent Osteointegrável Implantation), shown in the Fig. 5b.



(a) (b)

Figure 5. Electronic torque controller (a) and surgical torquemeter ratchet (b) used in the simulation of surgical placement

4. Analytical model

Parallel, an analytical model was developed to determine the values of the theoretical angles of rotational freedom. This model is similar to the model of Lang *et al.* (2002). In this in case, the main objective of this approach is to validate the analytical model in accordance with the experimental data. Figure 6 shows the schematic drawing of the internal hexagon of the abutment located with the external hexagon of the implant. The rotational freedom is defined by the angle (α) formed by the two lines that join the respective vertex with the central point (O).

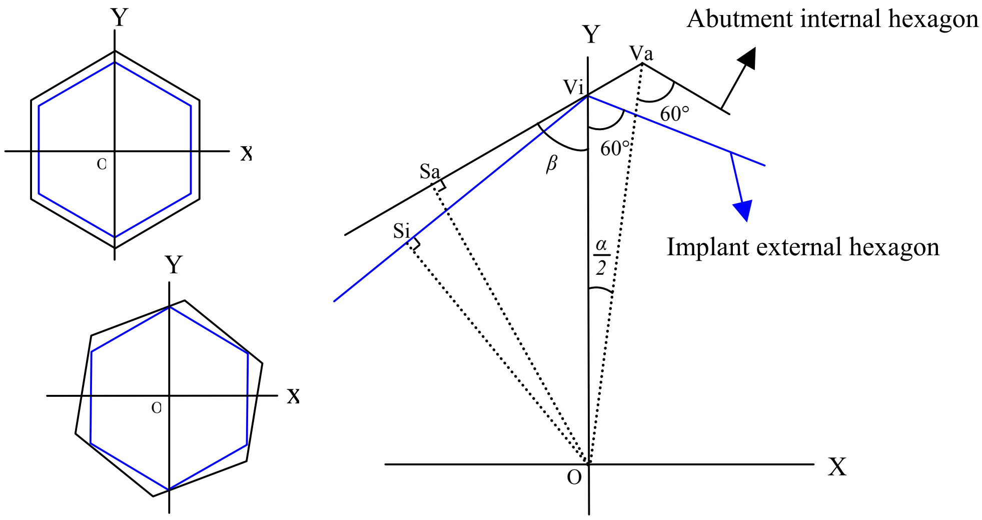


Figure 6. Schematic drawing for determination of the theoretical angle of rotational freedom

Of Figure 6 it can be defined the following geometric relations:

$$\overline{VaO} = \frac{\overline{SaO}}{sin\ 60} \tag{1}$$

Where: $\overline{VaO}$: Width between the vertex of the hexagon of the abutment until the central point
$\overline{SaO}$: Width between the center of the side of the hexagon of the abutment until the central point

$$\overline{ViO} = \frac{\overline{SiO}}{sin\ 60} \tag{2}$$

Where: $\overline{ViO}$: Width between the vertex of the hexagon of the implant until the central point
$\overline{SiO}$: Width between the center of the side of the hexagon of the implant until the central point

$$\overline{ViSa} = \sqrt{\overline{ViO}^2 - \overline{SaO}^2} \quad (3)$$

Where: $\overline{ViSa}$: Width between the vertex of the hexagon of the implant until the center of the side of the hexagon of the abutment

$$\overline{VaVi} = \left[\frac{\overline{SaO}}{tan\,60} \right] - \overline{ViSa} \quad (4)$$

Where: $\overline{VaVi}$: Width between the vertex of the hexagon of the abutment until the vertex of the hexagon of the implant

$$\beta = tan^{-1}\left(\frac{\overline{SaO}}{\overline{ViSa}} \right) \quad (5)$$

$$X_i = \overline{VaVi}\, sin\beta \quad (6)$$

$$Y_i = \overline{ViO} + \overline{VaVi}\, cos\,\beta \quad (7)$$

Of equations (1) to (7), the value of the theoretical angle of rotational freedom is taken as following:

$$\alpha = 2\left(tan^{-1} \frac{X_i}{Y_i} \right) \quad (8)$$

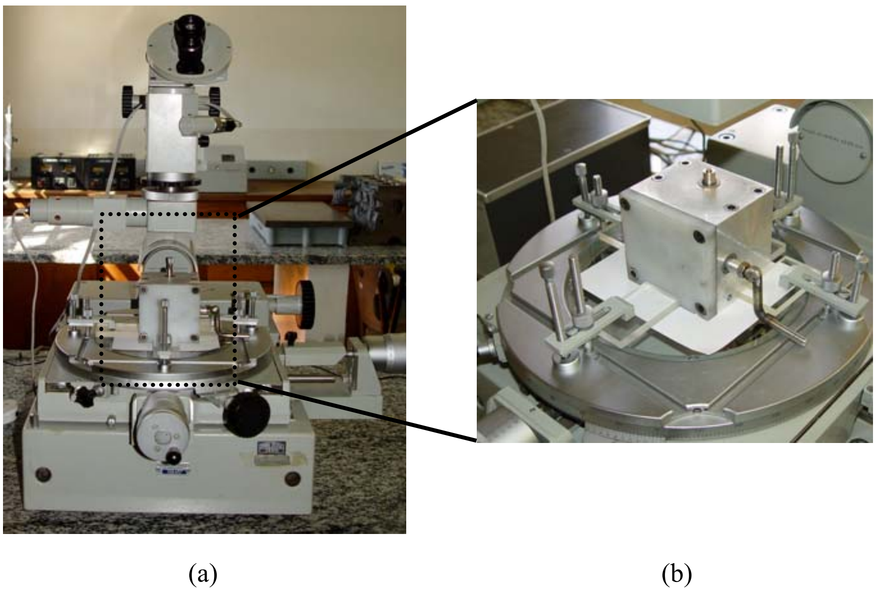
4.1. Measurement of the theoretical rotational freedom

As shown in the equations (1) to (8), the theoretical rotational freedom (α) can be taken simply measuring the distances of the average points of the sides of the hexagons to the center ($\overline{SaO}$) e ($\overline{SiO}$).

The theoretical values of the rotational angles had been determined for the ten samples of EH implants and ten samples of IT implants, submitted to the four levels of torque: null, 45 N cm, 60 N cm and 80 N cm.

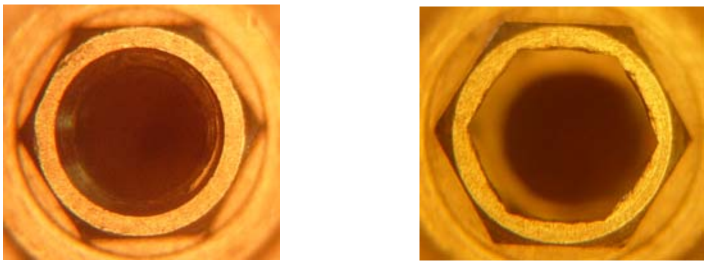
The samples were analyzed successively after the application of the torque in a microscope with increase of 20 times, shown in the Fig. 7a. For each sample the average values of $\overline{SaO}$ and $\overline{SiO}$ were determined, for then determining the values of rotational freedom consequently and its average values.

The Figure 7b shows the device suitable to the microscope to turn the sample in the same position of reference. Figure 8 shows to the images of the EH and IT implants in analysis in the tool microscope (Karl Zeiss Jane).



(a) (b)

Figure 7. Tool microscope (a) and device used in the measurement (b).



(a) (b)

Figure 8. Images of the implants EH (a) and IT (b) in analysis in the microscope.

5. Results

The average values of the widths of the implants hexagon measured in the microscope for the analyzed samples, as described in section 4.1, under different levels of torque, are shown in Fig. 9.

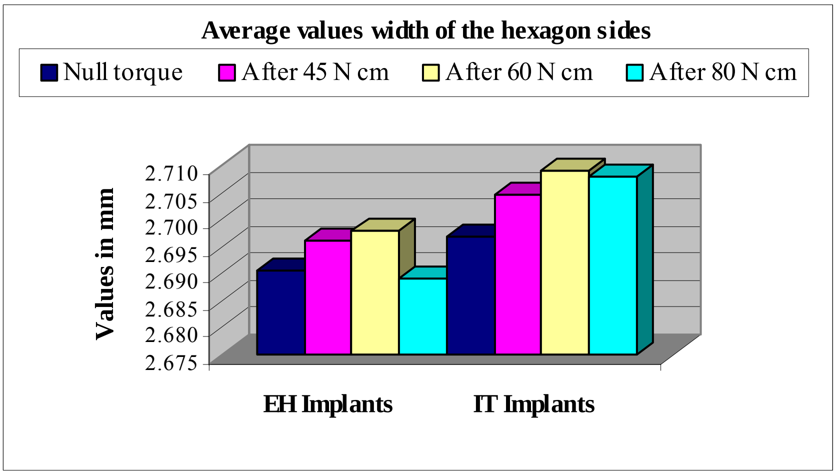


Figure 9. Average values width between the three sides of the implants hexagons under different levels of torque.

With the aim to verify the existence or not of significant differences between the values of the hexagons widths of the implants, the data had been submitted to Student's *t* test (p<0,05), with the aid of statistical program SPSS (SPSS, Chicago, IL). After the application of the statistical test was evidenced significant difference between the values of EH and IT, under the different levels of torque: null, 45 N cm, 60 N cm and 80 N cm. Was also observed that the values of the hexagons widths of the implants IT had been presented higher than of EH implants, under different levels of torque.

The connection of the abutment to the external hexagon of the implants EH and IT needs to be trustworthy for the appropriate functioning and the stability of the prosthesis over implants (Merz, Hunenbart and Belser, 2000). For this to occur, the differences between the dimensions of the hexagons of the abutment and the respective implant must be minimum, propitiating passive adjustment of the components and preventing the emergence of stress in the screw due to the rotational misfit (Me, Nicholls and Rubenstein, 1997).

In Figure 9 a similar behavior in the two types of analyzed implants is observed, with exception of the EH for the torque of 80 N cm. In this case, the connection did not support the level of applied torque, deforming the vertex and diminishing the widths between the sides of the hexagons.

5.1. Angles of rotational freedom

The angles of rotational freedom of the experimental model had been submitted to Student's *t* test (p<0,05), with the aid of statistical program SPSS (SPSS, Chicago, IL). In accordance with the results presented in Tab. 1, there was not significant difference for the angles of the implants under null torque for the systems EH and IT. The same result was observed for the implants submitted to the torque of 45 N cm.

For the torque of 60 N cm, there was significant difference (*P*<.05) between the systems EH and IT. In this case, it was observed that the values of EH had been higher than IT. After torque of 80 N cm, the vertex of EH implants had become deformed, annulling its antirotational effect, disabling the measure of the respective angles.

Table 1. Average values of the rotational angles for EH and IT in the experimental and analytical models, and relative error of the averages.

ROTATIONAL FREEDOM						
Torque	Experimental		Analytical		Relative error of the average [(2)]	
	HE [(1)]	TI	HE	TI	HE	TI
Null	3.308 [a]	3.140 [a]	3.595	3.244	8.67%	3.31%
45 N cm	3.274 [a]	3.197 [a]	3.299	3.723	0.76%	16.45%
60 N cm	4.029[b]	3.534 [a]	4.573	3.926	13.5%	11.09%
80 N cm		3.591		4.007		11.58%

[(1)]: For torques of the order of 80 N cm the vertex of the external hexagon had become deformed, annulling its antirotational effect.

[(2)]: Relative error of the averages of the experimental model and the analytical model (%).

It is observed in Tab. 1 that the biggest relative error between the theoretical and experimental results was of the 16.5% order. It must be showed up that the experimental measures had been used to adjust the analytical model, through the identification of the order of magnitude of the analytical measures.

Figure 10 shows the measured experimental rotational angles for the samples of EH implants, under the different levels of torque. It can be observed that the rotational angles had increased with the increase of the applied torque.

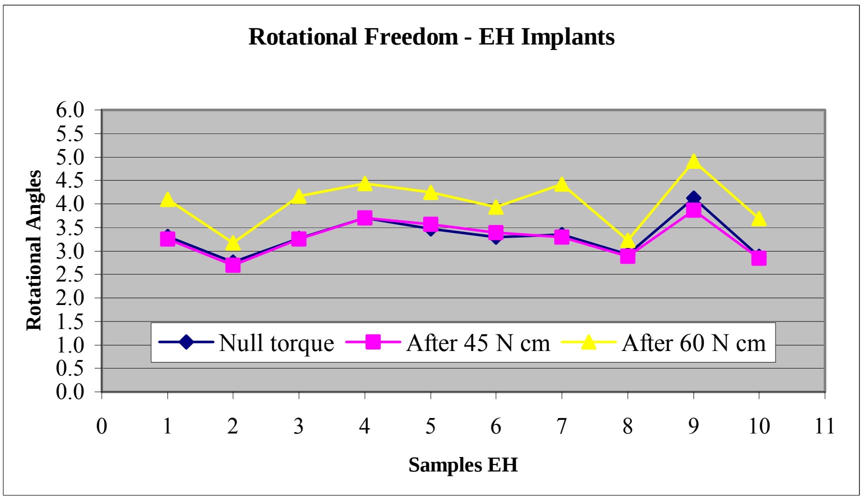


Figure 10. Experimental rotational freedom for 10 EH implants under torques null, 45 N cm and 60 N cm.

Figure 11 shows the experimental rotational angles measured for the samples of the IT implants, under the different levels of torque. As for the implants EH, rotational angles had also increased with the increase of the applied torque.

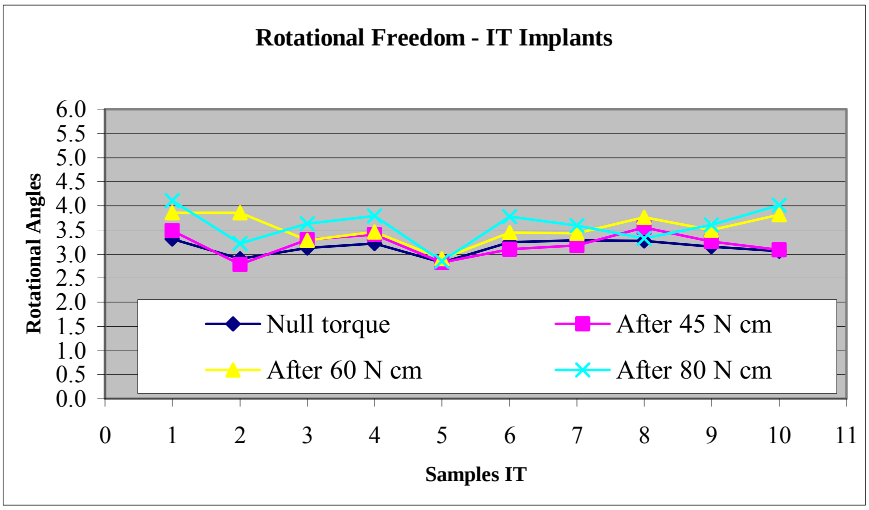


Figure 11. Experimental rotational freedom for the 10 IT implants under torques null, 45 N cm, 60 N cm and 80 N cm.

According to Binon (1996), the joint stiffness and the preload are compromised when the rotational angles are more than 5 degrees, leading the screwed junction failing by screw loosening and movement of the abutment. In the present work it is observed that the EH and IT implants had kept the angles of rotational freedom below 5 degrees, under the different levels of torque. But under the torque of 80 N cm, was impossible to measure the EH implants, due to deformation of the connection.

When compared 45 N cm to the null torque, as between EH implants as between IT implants, the samples had presented similar behavior. Comparing the torque of 60 N cm with the previous ones, there was significant difference (P<.05) as for EH implants as for IT implants. For the torque of 80 N cm, the IT implants showed no significant difference comparing the torque of 60 N cm. But when comparing with the torque of 45 N cm and null torque there were significant difference between the samples.

6. Conclusions

This work is part of a subject of Master dissertation inside of a research line in implantology involving the graduate programs in Dentistry and Mechanical Engineering of the Federal University of Uberlândia.

An experimental and theoretical evaluation for the attainment of the rotational freedom angles in dental implants was presented. These parameters depend on the type of implant used and influence, mainly, the insertion and longevity of the implant.

It can be concluded that, under conditions of null torque and with 45 N cm, IT and EH implants have similar rotational freedom. When the external torques applied to the implants increase, it is observed that the IT implant have a behavior more stable with relation to the values of the rotational freedom. After the torque of 60 N cm, the rotational freedom for EH implant increased about 0.7° and for the IT implant it increased about 0.4°, having as reference the experimental results.

The results indicate that the IT implant could support higher levels of torque and therefore do not influence the integrity of implant-abutment interface.

However, other analyses are necessary in order to adequately evaluate the physical behavior of the researched implants.

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