Analysis of Implant Hexagon Deformation Degree of Dental Subject to Standard Torques

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Abstract

Introduction: *Dental implants constituted a valuable contribution to the dental replacement due to high functional and aesthetic quality. The implants with external hexagon (HE) are examples of dental implants, since they use the rotational force transfer mechanism applied on the external face of the HE (external torque) or at thinner HE (internal torque), among other ways installation, to allow the insertion of the implant in the bone. One should always be careful, however, to the fact that this type of rehabilitation treatment requires control of certain strength of implant placement in bone bases, avoiding result in deformation of the hexagon structure.* ***Objective****: To evaluate the maintenance of the physical integrity of the surface of the outer hexagon is dental implants HE type manufactured by Nobel Bio care, after application of internal or external torques installation in vitro through digitized optical images.* ***Method****: To study the maintenance hexagon integrity after application of sequential torques were used as body-specimens implants produced by Nobel Bio care fixed on a standardized metal deck, while for the application of torques ∞ and 35, 45 and 70 N / cm was used a specific manual torque wrench manufacturer of Nobel Bio care implants. Completed the application procedures of internal and external torques, photographed external hexagons implants studied and scanned images, proceeded to the measurements of the area, perimeter, diameter and distance side by side with the aid of a specific software, AutoCAD followed by the statistical treatment of the data.* ***Results****: Considered zero torque, the image corresponding to the original area of the external hex implant compared to images of the same area after application of external torques35, 45 and 70 N / cm was shown that there was no change at all in hexagonal structure. This same phenomenon was repeated to be zero torque images confronted with the images obtained after these same torques directly related to the perimeter, diameter and measures side by side. The images of the external hex implant external torque corresponding to zero when confronted with the images obtained after infinite external torque indicate changes have occurred in the hexagon size. As for the internal torque applied to the external hexagon implant finds itself no alteration in any dimensions measured, including in relation to the infinite torque.* ***Conclusion****: According to the methodology, it is concluded that the application of external torques external hexagons implants Nobel Bio care brand only causes change in dimensions is imposed torque ∞. However, the structure is preserved external hexagon implants while imposing torque ∞, provided it is applied internally.*

Keywords: Dental techniques; tools, materials and surgical research.

A relevant portion of oral rehabilitations can be solved with the use of dental implants, which are alternatives that can satisfactorily return the form, function and aesthetics of dental units.

However, one should be aware of the fact that this type of rehabilitation treatment requires a certain strength of the implant placement in bone bases, which may result in deformations in the implant itself and, in particular, in the structure responsible for the prosthetic connection, namely, the hexagon. Therefore, the passive fit of an implant-supported prosthesis and its components is critical for successful treatment. Implants with external hexagons are examples of dental implants that are used as rotational force transfer, aiming at an alternative insertion of the implant in the bone. These implants are used in implant-supported prostheses units as guidelines for positioning abutments (1). In implants with external hexagons, the use of high rotational force during the insertion into the bone results in a low micro drive into the interface (2, 3). However, when these forces are applied to the outer surface of the hexagon (external torque), adverse changes to their geometry can be produced (4), (5). These changes interfere with the rotational freedom between the abutment and the implant and, thus, the passive fit of the prosthesis on the implant (6, 7). To reduce the negative aspects of the external torque, the application of the rotational force to the inner surface of the outer hexagon (internal torque) has been suggested because this area has a greater resistance compared with the external surface (6, 8).

The adaptation between the external hexagon of the implant and the internal hexagon pillar, which is defined as the rotational freedom, also plays an important role in the stability of a bolted joint. A precise adaptation between these two components is a possible mechanism to prevent slack and loss of pre-load (9, 10). To ensure a stable union of the screwed components, the two hexagons contacts must allow a freedom of rotation less than 5 degrees between the inner pillar and the outer hexagon of the implant hexagon (6, 11, 12). The rotational freedom of the customizable pillars obtained by the Nobel Bio Care implants, which are considered ideal in many studies, is considered acceptable within the levels suggested by the literature, confirming the quality of the implant and its components (13). Mismatches that produce discrepancies or micro gaps larger than 10 microns may cause biological consequences that lead to bacterial micro-infiltrations (14, 15, 16) and mechanical instability leading to the screw loosening, which indicate the failure of treatment (17). Mechanical complications are important in implant therapy (18, 19, 20), and screw loosening appears to be the most frequent complication in implant-supported prostheses, especially in the case of single restorations (19, 20). Connection systems with external hexagons are prone to unscrew due to their own mechanical properties (21, 22, 23, 24). The internal connection system was designed to minimize such occurrences. Thus, internal hexagonal connections exhibit significant biomechanical advantages compared with external hexagonal connections, such as a better distribution of forces under a mechanical load, increased stability due to a wider area connection and increased resistance to lateral movements during functioning (24).

Uncertainty of the predictability in the marginal adaptation led to the use of external hexagon prosthetic connections to an objectionable level considering all of the mismatch consequences at the interface between the implants and abutments. Specifically, as the abutment retaining screws loosen, bacterial infiltration with subsequent peri-implant inflammation, increased marginal bone loss and, in more severe cases, loss of osseo integration are noted. (25, 26, 27). Despite the finding that external hexagon implants are well accepted, the occurrence limitations should be noted because the height of the implant is limited to 1.0 mm to ensure the final aesthetics of the implant-supported prosthesis. Regarding the complications that may relate to the external hexagon, the appearance of deformations during implant insertion can occur(29). The dimensional accuracy ensures the coupling of the prosthetic component without clearances. The induction of stress in the coronary region due to an implant-component mismatch bio film favours the adhesion at the edge of the implant after the induction of the saucerisation platform. The accuracy of the hexagon dimensions is essential to ensure the stability of the prosthesis to minimize the loosening of the prosthetic screw, allow proper seating of the prosthesis to create vertical and horizontal adjustment of the intermediate pillar in the implant platform and prevent the migration of bacteria to the inner hole of the implant (29). Therefore, it is important to assess the degree of the structural deformation in the external hexagon implants after submission of these elements using installation torques with standardized and sequential values.

Materials and Methods

Two experimental groups (GExp1 and GExp2) were formed for three implants, each aimed at evaluating the maintenance of the hexagon integrity after sequential torque application. We chose implants produced by Nobel Bio Care because the manufacturer has an international recognition in the field of implant-supported dental restorations. For the torque application, a metallic base was created for the purpose of stabilizing the bodies of the test piece and the subsequent application of torques (24, 29).

This device consists of two stainless steel platforms that are bolted together with a central hole with a 3.5-mm slit to position the implant to render the torques (Figure 1). All sample implants were placed with two threads above the device level and tightened with the aid of two screws to standardize the tests.

Figure 1-Base to stabilize bodies-proof

For the application of torques, a specific manual torque wrench manufactured by Nobel BioCare was used. This is a manual device that provides numeric scale readings in Newton's (N.cm), through which four fixed values serve as standardized torque values set by the manufacturer as follows: T1 = 35 N / cm; T2 = 45 N / cm; T3 = 70 N / cm; and T4 = ∞. After stabilization of the implant to the attachment platform (torque = zero) and the application of each torque (35, 45, 70 N/cm and ∞), respective images were obtained by a stereoscopic Option microscope (NET-10B model). The images were scanned to identify concrete data of possible deformations of the external hexagon of the bodies of the test piece under study. Scanned images were obtained and revealed a final 29-fold increase in the measurements of the area, perimeter, diameter and side-by-side distance with the help of specific software (Figures 2 and 3).

Figure 2 - Graphical representation of the measurements of the area, perimeter, diameter and side-to-side of the hexagon

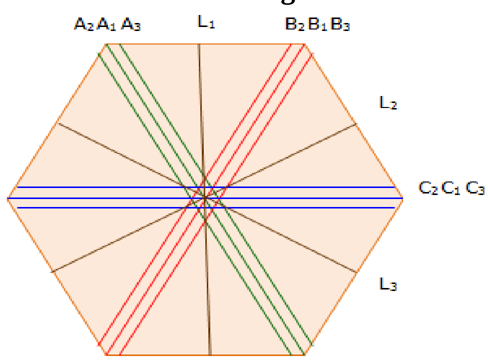
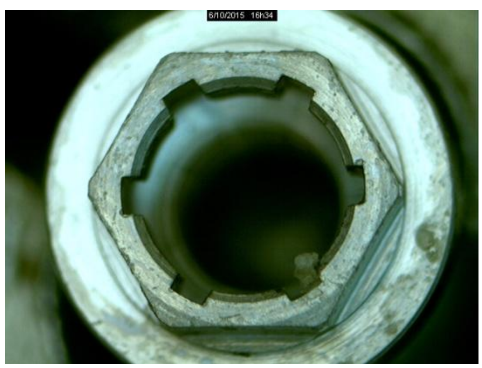


Figure 3 - Photograph of representative measurements of the area, perimeter, diameter and side-to-side of the hexagon



To extract the final measures of the deformations in the external hexagons (HE) of the dental implants in the study, individual photographs of the tested parts were analysed, and worksheets with the results were evaluated using Microsoft Excel.

Thus, the methodology used in this project involved the AutoCAD software to apply a full-scale analysis of the photos to precisely design the hexagon shape. AutoCAD is 3D CAD software that is used for designing, modelling and engineering and allows the preparation of all final designs. The images of the dental implants obtained perpendicular to the platform allow the study of the upper faces of the hexagons to be tested after a full-scale application. Each image had the outline of the HE transformed into a precise design based on the measurements and revealed how each HE was deformed in a unique way. Although its design was possible using the measured area and perimeter, further measurements were obtained to assess each torque and its ability to cause deformation in the implant structure. Despite being a suitable technique for the study of these deformations, some errors are possibly present in these measurements, which highlight a limitation of the study. Another error is the aggregator that draws the image. Thus, it is necessary to consider the sources of error in the final results to increase the confidence interval and ensure an enhanced reliability of the measurements. To assess the degree of distortion of the resulting images, the differences in the larger diameters (A1, B1 and C1) were assessed followed by a calculation of the arithmetic mean of these differences in the bodies of the test piece. Values close or equal to zero indicate no distortion in the hexagon symmetry. To reduce the chance of any image distortion likely to interfere with the results, inferential statistics were estimated with a confidence level of 99% and a consequent α significance level of 0.01. For comparisons of hexagon measures, the external and internal torque was assessed using one-way analysis of variance (ANOVA)because the assumptions were met as assessed by the Bartlett homo scedasticity test. For the comparison of the groups together in a two-by-two fashion, we opted for the multiple comparison test of Tukey. The analyses were performed using statistical software R version 3.2.2 (R Development Core Team, 2015).

Results

To correct possible distortions in the images due to permissible interference while obtaining the photographs, such as brightness, we sought to identify the difference between the diameters determined by consistently using the largest value (A1, B1 and C1) as a reference. Table 1 presents the average of the calculated differences reported in millimetres (bias). As noted in the table below, the bias was only 0.02 mm for the three largest diameters, indicating a symmetric hexagon associated with a small image distortion.

Table 1 - Difference of largest diameter

Difference	Media (bias) mm
$A_1 - B_1$	0,02
$A_1 - C_1$	0,02
$B_1 - C_1$	0,02

A1, B1 and C1 = three largest diameters HE

Table 2 - Mean, standard deviation and maximum and minimum values of the HE area during the external torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	6,40	0,05	6,36	6,46	a
35	6,34	0,01	6,33	6,34	a
45	6,36	0,05	6,32	6,42	a
70	6,27	0,10	6,19	6,38	a
∞	5,86	0,12	5,72	5,96	b

Bartlett Test. p = 0,062. ANOVA (p = 0,000038).
*Tukey Test: 99%

Table 3 - Mean, standard deviation and maximum and minimum values of the HE perimeter during the external torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	9,29	0,03	9,27	9,33	a
35	9,27	0,04	9,23	9,30	a
45	9,27	0,03	9,25	9,30	a
70	9,21	0,06	9,16	9,28	a
∞	8,83	0,12	8,69	8,93	b

Bartlett Test. p = 0,24. ANOVA (p = 0,000036).
*Tukey Test: 99%

Table 4 - Mean, standard deviation and maximum and minimum values of the side-by-side measurement of L1 HE during the external torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,71	0,01	2,70	2,72	a
35	2,70	0,01	2,69	2,71	a
45	2,71	0,03	2,69	2,74	a
70	2,69	0,03	2,66	2,71	a
∞	2,60	0,02	2,58	2,62	b

Bartlett Test. p = 0,62. ANOVA (p = 0,00018).
* Tukey Test: 99%

Table 5 - Mean, standard deviation and maximum and minimum values of the side-by-side measurement of L2 HE during the external torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,72	0,02	2,70	2,74	a
35	2,71	0,01	2,70	2,71	a
45	2,70	0,01	2,69	2,71	a
70	2,69	0,03	2,67	2,72	a
∞	2,62	0,02	2,60	2,63	b

Bartlett Test. p = 0,42. ANOVA (p = 0,00024)
*Tukey Test: 99%

Table 6 - Mean, standard deviation and maximum and minimum values of the side-by-side measurement of L3 HE during the external torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,73	0,01	2,72	2,74	a
35	2,72	0,01	2,71	2,73	a
45	2,72	0,01	2,71	2,73	a
70	2,71	0,02	2,69	2,73	a
∞	2,63	0,02	2,60	2,64	b

Teste de Bartlett. Valor de p = 0,69. ANOVA (p = 0,000092).
*Teste de Tukey: 99%

Table 7 - Mean, standard deviation and maximum and minimum diameter of the HE area during the internal torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	6,38	0,07	6,31	6,44	a
35	6,38	0,02	6,35	6,39	a
45	6,43	0,04	6,40	6,47	a
70	6,38	0,04	6,34	6,41	a
∞	6,43	0,08	6,38	6,52	a

Teste de Bartlett Test. p = 0,56. ANOVA (p = 0,5).
*Tukey Test: 99%

Table 8 - Mean, standard deviation and maximum and minimum values of the HE perimeter during the internal torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	9,30	0,04	9,25	9,33	a
35	9,29	0,01	9,28	9,30	a
45	9,33	0,03	9,31	9,37	a
70	9,29	0,03	9,26	9,32	a
∞	9,32	0,06	9,28	9,39	a

Bartlett Test. p = 0,45. ANOVA (p = 0,66).
*Tukey Test: 99%

Table 9 - Mean, standard deviation and maximum and minimum values of the L1 HE during the internal torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,70	0,03	2,68	2,73	a
35	2,70	0,01	2,70	2,71	a
45	2,72	0,02	2,70	2,73	a
70	2,70	0,01	2,70	2,71	a
∞	2,73	0,02	2,72	2,75	a

Teste de Bartlett Test. p = 0,3. ANOVA (p = 0,22).
*Tukey Test: 99%

Table 10 - Mean, standard deviation and maximum and minimum values of the L2 HE during the internal torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,71	0,01	2,70	2,72	a
35	2,71	0,01	2,71	2,72	a
45	2,73	0,01	2,72	2,74	a
70	2,71	0,02	2,69	2,72	a
∞	2,72	0,02	2,70	2,74	a

Bartlett Test. p = 0,58. ANOVA (p = 0,32)
*Teste de Tukey Test: 99%

Table11- Mean, standard deviation and maximum and minimum values of the L3 HE during the internal torque application

Torque	Média	DP	Min	Max	Comparação múltipla*
0	2,72	0,02	2,71	2,74	a
35	2,72	0,01	2,71	2,73	a
45	2,73	0,01	2,72	2,74	a
70	2,73	0,01	2,72	2,73	a
∞	2,73	0,02	2,72	2,75	a

Bartlett Test. p = 0,79. ANOVA (p = 0,74).
* Tukey Test: 99%

Discussion

Regarding the reliability of the reproduced images, the scanning of the external hexagon of the dental implants manufactured by Nobel Bio Care led to the evaluation of the three largest diameters using a regular geometric figure view; therefore, the diameters and sides are theoretically equal**(23)**.

The differences from a statistical point of view revealed a bias of 0.02 mm (Table 1). This finding indicates a symmetrical hexagon with a small image distortion; however, this distortion is not significant because the measurement of the largest diameter was approximately 3.02. This phenomenon resulted from possible inaccuracies in the desirable uniform light, the fact that the images are not strictly perpendicular to the implant platform and the limited accuracy to reproduce the contour of the figure in the construction drawing of the image using AutoCAD. This understanding is justified in the confidence interval given that the statistical treatment ensured the enhanced credibility of the measurements. However, using increased precision to follow the contour of the external hexagon, we cannot ensure that the design is a faithful representation of the actual values. Thus, it was essential to consider the sources of error in the final result.

At zero torque, the image corresponding to the original area of the external hexagon compared with images of the same area after the application of external torque values 35, 45 and 70 N/cm (Table 2) reveals no alteration in the hexagonal structure statistically because all of the measures compared in pairs are located within the confidence interval. This same phenomenon is repeated by comparing images obtained at zero torque with images obtained after 35, 45 and 70 N/cm. Specifically, the perimeters, side-to-side measurements and diameters were compared (Tables 3, 4 and 5). When the same images of the external hexagon with no external torque (zero) are compared with the images obtained after infinite external torque, changes in the hexagon dimensions, including the area, perimeter, diameter or side-by-side distance, were noted as the measurements are beyond the confidence intervals recorded by the statistical tests. Regarding the internal torque applied to external implants, the hexagons did not exhibit any changes in area, perimeter, diameter or side-by-side measurements (Tables 6, 7, 8 and 9). This finding is the result of multiple pair wise comparisons between all torques with an emphasis on the infinite marker. The accuracy of the hexagon dimensions is essential to ensure the stability of the prosthesis to minimize loosening of the prosthetic screw, allow proper seating of the prosthesis to create vertical and horizontal adjustment of the intermediate pillar in the implant platform and prevent the infiltration of microorganisms into the implant (23). Considering the importance of reducing the negative aspects of the external torque implant, the application of rotational force to the inner surface of the HE is suggested. It should be noted that this surface exhibits greater strength compared with the outer surface (6, 8, 24). It is assumed that implants that have an external hexagon for the prosthetic connection and an internal torque for the surgical installation phase can ensure greater stability of the denture and implant system. This understanding can improve and facilitate the surgical installation given that a single implant offers the versatility of the external hexagon connection with the security of the internal torque (10).

Conclusion

Based on the results of the present study, it can be concluded that the possibility of distortion of the external hexagon of the implant manufactured by Nobel Bio Care can exceed the limit of 70 N/cm via external torques. Thus, the infinite marker can be used when conducting internal torques without the risk of any statistically significant distortion of the external hexagon.

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