

ACCURACY OF IMPLANT TORQUE CONTROLLERS FOLLOWING TIME IN CLINICAL SERVICE

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ABSTRACT

Background and Aim: The purpose of this study was to evaluate the accuracy of ten implant systems torque wrenches in delivering the target torque values following time in clinical service.

Materials and Methods: Eleven torque controllers from Nobel Biocare (Nobel Biocare Inc., Yorba Linda, CA), Camlog (Biotechnologies AG, Basel, Switzerland), Friadent (Dentsply-Friadent, Mannheim, Germany), Straumann (Straumann AG, Basel, Switzerland), SwissPlus (Zimmer Dental, Carlsbad, CA), Astra Tech (Astra Tech Inc., Waltham, MA), Tapered screw-vent (Zimmer Dental, Carlsbad, CA), Bio-Lok (International Inc., Deerfield Beach, FL), Anthogyr (Sallanches, France), BioHorizons, (Maestro Dental Implants, Birmingham, AL), Thommen (Thommen Medical AG, Waldenburg, Switzerland), which had been in clinical service for a maximum one year were tested. An implant, along with an attached abutment and abutment titanium screw, was held firmly in a Tohnichi torque gauge. Calibration accuracy for the Tohnichi is $\pm 2\%$ of the scale value. Ten torque values (10, 14, 15, 20, 24, 25, 30, 32, 35, and 45 N-cm) were tested. The data for each group were evaluated using a statistical software package with a significance level of .05.

Results: Significant differences generally existed between the individual units and the target torque values for all the tested devices except Friadent. The tested devices of the Friadent, Straumann, SwissPlus and Astra Tech implant systems were capable of providing consistent torque at or near to their respective targets although the torque output of each individual device deviated from target torque value in varying degrees.

Conclusion: The torque output of each individual device deviated in varying degrees from target torque values.

Key words: Biomechanics, Dental Implant, Mechanical Stress, Screw Loosening, Torque Driver

INTRODUCTION

Unintentional loosening of screw components is a frequent problem related to dental implants.^{1,2} It has been stated that complications such as screw fracture or damaged abutment screw components are related to screw loosening.²⁻⁴ Early studies of implant-supported restorations indicate abutment screw loosening at a rate of 31% during the first year.^{2,5} Although the design of screw head and screw material may be important for screw joint stability; the nature of loosening or displacement of prosthetic components is complex, since it can be attributed to several causes, including inadequate screw tightening, poorly machined components, nonpassive, cantilevered or poorly fitting prosthesis, or excessive loading and screw design.⁶⁻¹⁰ Jörn  us et al.⁸ suggested that the inadequate tightening may be the cause of loosening of the screw while in function. However, excessive torque that exceeds the yield strength of the screw shank leads to screw fracture over time arising from the load fatigue associated with mastication forces.⁷ In short, screws that are under-tightened can become loose. Screws that are over-tightened can fracture either at insertion or after application of functional loading cycles.⁹ In a screw joint complex, a screw tightens together a unit comprised of 2 parts.⁹⁻¹² The applied torque is distributed to the screw joint through friction between the screw head and prosthetic abutment, friction between the threads on the screw and the internal threads of the implant, and the tension within the screw known as preload.^{10,13} The closer tightening force approaches to the recommended force for any particular screw, the more stable the connection will be.^{8,10,11} A hand driver is not recommended for final screw tightening because it is difficult to generate more than 20 N-cm. of torque, and because it results in inadequate preload to the implant screw joint.^{2,10-13} Manufacturers recommend the use of torque limiting devices to ensure the adequate torque delivery, thereby reducing the unintentional screw loosening during service.¹² A variety of devices, both mechanical and electronically, have been developed to place controlled torque levels on dental implant systems.^{2,4,9} The mechanical torque limiting devices are usually pre-calibrated by the manufacturer to apply torque to the screw joint, and are available either in friction style or spring style.¹⁰ Electronic torque controllers, typically in the form of a latch-type dental hand piece, are also available to deliver specific desired torque.¹² As screw loosening, screw fracture and other complications within the implant systems have mainly been attributed to under or over screw tightening,

the accuracy and consistency of torque limiting devices are of the utmost importance.^{7,14} There are several studies in literature concerning the torque delivery accessories of several implant systems.^{2,4,7,9} However, there is a lack of research which compares different implant systems torque devices. Therefore, the present in vitro study aimed to investigate the torque devices of ten different implant systems in-vitro for their accuracy of torque delivery.

MATERIALS AND METHODS

In the current study, the torque delivery accuracies of the torque controllers for Nobel Biocare (Nobel Biocare Inc., Yorba Linda, CA), Camlog (Biotechnologies AG, Basel, Switzerland), Friadent (Dentsply-Friadent, Mannheim, Germany), Straumann (Straumann AG, Basel, Switzerland), SwissPlus (Zimmer Dental, Carlsbad, CA), Astra Tech (Astra Tech Inc., Waltham, MA), Tapered screw-vent (Zimmer Dental, Carlsbad, CA), Bio-Lok (International Inc., Deerfield Beach, FL), Anthogyr (Sallanches, France), BioHorizons, (Maestro Dental Implants, Birmingham, AL), Thommen (Thommen Medical AG, Waldenburg, Switzerland) were tested. The tested torque controllers except DEA 020, which is an electronic torque controller (Nobel Biocare), were mechanical drivers. All wrenches had been in clinical service for one year without recalibration since the time of their purchase. As the torque devices were used by different users, no standardization could be made considering the sterilization procedures after each use; however, all torque devices were reported to be used approximately 15 to 20 times weekly. Torque delivery accuracy was measured using a technique that simulated the clinical situation. The implants were modified by creating 2 flat surfaces, each 4 mm in width, on the threaded cylindrical section of the implant. When the implants were secured in the 3-jaw chuck of the Tohnichi torque gauge (Model BTG02 Tohnichi MFG. Co., Ltd, Tokyo, Japan), the flat surfaces prevented implant rotation under torque when the implant was clamped in the torque gauge. Although the Tohnichi torque gauge is calibrated at the factory to be accurate within $\pm 2\%$ of the scale value with 0-60 N-cm measurement range and accuracy, the accuracy of the Tohnichi torque gauge was tested prior to data collection. An L-shaped rod with a groove to locate load location was clamped in the chuck of the gauge. With the gauge lying horizontally, accurately known loads were placed on this cantilever. With a known distance from the groove to the center of the 3-jaw chuck, the applied torques could be calculated. These known

torque values were compared with the values recorded by the torque indicator on the gauge. The error was found to be within the $\pm 2\%$ specification given by the manufacturer. The steps used in testing each torque controller were as follows:

1. The implant was clamped in the 3-jaw chuck of the Tohnichi torque gauge. (Figure 1)
2. The torque indicator on the gauge was set to zero. This indicator rotated to mark the peak torque value delivered and remained there following torque removal.
3. The controller was set to the required torque and speed settings. The torque controller was used to torque the titanium screw to the preset torque value. Care was taken to ensure that the torque controller was collinear with the implant during torque application. (Figure 2)
4. While the torque controller was held in one hand and the gauge was held in the pressing machine (Figure 2), the controller was activated. During this operation, the titanium screw turned a minimum of half a rotation before the full torque value was attained. This was done to simulate clinical conditions.
5. The peak torque value registered by the torque indicator was read and recorded.

Steps 1 to 5 were repeated 10 times sequentially for each torque controller, and all torque readings were done by the same investigator for standardization. The torque levels recommended by the manufacturers for various implant abutment screws were as follows: 10 N-cm for Bränemark, Camlog, AstraTech, Anthogyr (T10 group); 14 N-cm for Friadent (T14 group); 15 N-cm for Straumann, AstraTech, Anthogyr, Thommen (T15 group); 20 N-cm for Bränemark, Camlog, SwissPlus, AstraTech, Anthogyr, Tapered screw-vent (T20 group); 24 N-cm for Friadent (T24 group); 25 N-cm for AstraTech, Anthogyr, Thommen (T25 group), 30 N-cm for, Camlog, SwissPlus, BioloK, Biohorizons, Tapered screw-vent, Thommen (T30 group), 32 N-cm for Bränemark (T32 group); 35 N-cm for Straumann, Anthogyr, Thommen (T35 group); 45 N-cm for Bränemark (T45 group).

The data were evaluated with One sample t-tests for detecting the statistically significant variations from the target torque value for each group using a statistical software package (SPSS 11.0, SPSS INC., USA) at a significance level of .05.

RESULTS

Table 1 presents the differences found among implant systems torque wrench values. Significant differences



Figure 1. Torque delivery accuracy measured using a technique that simulated the clinical situation



Figure 2. The implants along with their respective healing abutments attached

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Table 1. Differences found among implant systems' torque wrench values.

Torque Values N-cm	Test Value	Brand Names	Mean	Std. Deviation	p
T-10	10	Bränemark	10.10	1.807	p>0.05
	10	Camlog	7.10	0.211	p=0.001
	10	AstraTech	9.15	0.709	
	10	Anthogyr	8.35	0.242	
T-14 T-15	14	Friadent	14.20	0.715	p>0.05
	15	Straumann	14.90	0.738	
	15	AstraTech	14.70	0.888	
	15	Anthogyr	14.00	0.667	p=0.001
	15	Thommen	15.60	0.395	
T-20	20	Bränemark	19.20	4.541	p>0.05
	20	Camlog	16.60	0.459	p=0.001
	20	SwissPlus	19.10	0.567	
	20	AstraTech	17.90	0.316	
	20	Anthogyr	17.50	0.666	
	20	Tapered screw-vent	17.10	1.173	
T-24 T-25	24	Friadent	23.90	0.211	p>0.05
	25	AstraTech	23.55	0.598	p=0.001
	25	Anthogyr	23.20	1.229	
	25	Thommen	24.20	0.182	
T-30 T-32	32	Bränemark	27.45	4.065	p=0.001
	30	Camlog	26.20	0.258	
	30	SwissPlus	27.00	0.471	
	30	BioloK	26.40	1.370	
	30	BioHorizons	26.00	1.433	
	30	Anthogyr	29.75	1.137	
	30	Tapered screw-vent	25.50	1.810	
	30	Thommen	28.87	0.283	
T-35	35	Straumann	33.40	0.966	p=0.001
	35	Anthogyr	32.70	1.494	
	35	Thommen	39.35	0.627	
T-45	45	Bränemark	34.35	3.028	p=0.001

generally existed between individual units and the target torque levels for the Nobel Biocare, Camlog, Straumann, SwissPlus, Astra Tech, Tapered screw-vent, Bio-Lok, Anthogyr, BioHorizons, Thommen implant systems torque

devices ($p < .05$). The mean torque values of the Friadent and Straumann implant system devices were within 5%, and the Astra Tech and SwissPlus devices were within 10.5 % of their respective target torque levels. The tested devices of

the Friadent, Straumann, SwissPlus and Astra Tech implant system in the present study were capable of providing consistent torque at or near to their respective targets although the torque output of each individual device deviated from target torque values in varying degrees.

For T-10 groups: The mean values were 10.1 N-cm for Brånemark, 7.1 N-cm for Camlog, 9.15 N-cm for Astra Tech and 8.35 N-cm for Anthogyr. The mean torque values for Anthogyr and Camlog similar, smaller than Astra Tech and also smaller than Brånemark. The difference between the target value and the value obtained with Anthogyr, Camlog, Astra Tech ($p < .05$) groups were statistically significant.

For T-14 and T-15 group: The mean values were 14.2 N-cm for Friadent, 14.9 N-cm for Straumann, 14.7 N-cm for Astra Tech, 14.0 N-cm for Anthogyr and 15.6 N-cm for Thommen. The mean torque values for Anthogyr was equal to Thommen but smaller than Astra Tech and also smaller than Friadent and Straumann. The difference between the target value and the value obtained with Anthogyr and Thommen groups were statistically significant ($p < .05$).

For T-20 group: The mean values were 19.2 N-cm for Brånemark, 16.6 N-cm for Camlog, 19.1 N-cm for SwissPlus, 17.9 N-cm for Astra Tech, 17.5 N-cm for Anthogyr and 17.1 N-cm for Tapered screw-vent. The mean torque values for Camlog was equal to Astra Tech, Anthogyr, Tapered screw-vent and SwissPlus but smaller than Brånemark. The difference between the target value and the value obtained with Camlog, Astra Tech, Anthogyr, Tapered screw-vent, SwissPlus were statistically significant ($p < .05$).

For T-24 and T-25 groups: The mean values were 23.9 N-cm for Friadent, 23.55 N-cm for Astra Tech, 23.2 N-cm for Anthogyr and 24.2 N-cm for Thommen. The mean torque values for Astra Tech was equal to Anthogyr and Thommen but smaller than Friadent. The difference between the target value and the values obtained with Astra Tech, Anthogyr and Thommen groups were statistically significant ($p < .05$).

For T-30 and T-32 groups: The mean values were 26.2 N-cm for Camlog, 27.0 N-cm for SwissPlus, 26.4 N-cm for Biolok, 26.0 N-cm for BioHorizons, 29.75 N-cm for Anthogyr, 25.5 N-cm for Tapered screw-vent, 27.45 N-cm for Brånemark and 28.87 N-cm for Thommen. The difference between the target value and the values obtained with all T-30 and T-32 groups were statistically significant ($p < .05$). For T-35 group evaluation, the mean values were 33.4 N-cm for Straumann, 32.7 N-cm for Anthogyr and 39.35 N-cm for Thommen. The differences were statistically significant for the systems in the T-35 group ($p < .05$).

For T-45 group evaluation, the mean value was 34.35 N-cm for the Brånemark system. The difference between the target value and the value obtained for the T-45 group was statistically significant ($p < .05$).

DISCUSSION

In the present study, the data revealed that the torque values measured deviated from the target torque values in varying degrees. There were significant differences among the products of different manufacturers. The Nobel Biocare, Camlog, and Anthogyr devices tested in this study were seen to demonstrate variations - more than %15- from the set target values that were almost as large as the errors seen in studies on application of torque by hand. Interestingly, torque output for the Thommen torque controller was above the target values for 15 N-cm and 35 N-cm-4% and 12 % respectively. It has been suggested that abutment screws can be torqued over their recommended target levels to increase retention or retorqued at frequent postinsertion intervals to achieve increased preload levels.⁹ However, according to the findings of this study, the Thommen device could not be employed in this way, because such overtorque application is useful as long as the excessive plastic deformation of the screw does not occur.⁹ The best results were found with the Friadent torque controller. The Straumann torque device tested delivered fairly consistent torque output- within 5% of their target values whereas the variations for the Astra Tech and SwissPlus systems were between 10 to 15 % of the target torque values. The findings of the present study for the Straumann system is in accordance with a previous study which compared the accuracy of three mechanical torque limiters, and found the means of the Straumann torque limiters within the 10% of the set target values.⁹ The Straumann mechanical torque limiter is a handheld ratchet-type torque wrench with no actual release mechanisms. Instead, the wrenches are inserted into a spring-activated sleeve with a scale preset by the manufacturer -torque targets of 15 and 35 N-cm. The operator applies force to the spring until the desired torque is achieved visually. Both Friadent and Straumann torque devices have their release mechanisms inside the screwdriver nut. This fact may explain the best results obtained with these systems.

The only electronic torque controller, DEA 020 for the Nobel Biocare system, tested in the present study uses an electrically controlled rheostat to apply precalibrated levels of torque to the appropriate driver. This device uses

a footactivated rheostat to drive the dental handpiece used to place implant components.¹³ Carlsson reported that the precision of this device is less than 10% when compared to the target values.¹⁵ However, a more than 20% variation was achieved with the Nobel Biocare torque controller for the 45 N-cm force in the present study.

For some time, screw loosening has been recognized as a significant problem in dental implant therapy.^{10,16-20} Screws have been extensively studied in the engineering literature and dental implant screws have improved as a result. Jörnér et al.⁸ noted that screw performance is related to the design, material, and insertion torque of the screw; however, dental implant assembly screws have inherent limitations in size, suitable materials, and the maximum torque applicable, so other strategies must be used to prevent loosening. An example of this limitation is the prosthetic (or retaining) screw, which reports have shown to loosen more readily than the larger abutment screw.^{8,21-23} The purpose of tightening restorative components on osseointegrated implants is to develop a preload tension in the system, thereby clamping the components together.² Bickford stated the stability of a screw joint is effected initially by the preload that clamps together the 2 components being jointed is tightened.²¹ Screws are usually placed under sufficient tension - termed preload - to resist the separating forces in function.²⁴ Screw joint failures or loosening occurs in 2 stages. The first consists of external functional loading that gradually leads to the effective erosion of the preload in the screwed joint. The screw can be thought as a spring, stretched by the preload, for which the stretch is maintained by the friction forces in the threads. Any transverse or axial external force that causes a small amount of slippage between the threads releases some of the stretch and some of the preload is lost.⁶ At this point, the greater the preload applied to a screw joint, up to a maximum equal to the ultimate strength, the greater the resistance to loosening and the more stable the joint, because the friction forces between the threads will be greater and a large external force is required to cause slippage. In the second stage of loosening, the preload is below a critical value so that external forces and vibrations cause the mating threads to turn or "back off".⁶ Hence, the preload generated by such screw tightening must be sufficient to prevent loosening of abutments and prostheses when subjected to functional loads. On the other hand, the preload must be limited to levels that will not result in ultimate material failure of the components, such as stripped threads or fractured abutment screws.²⁴

Therefore, the torque input should be controlled by the clinician to achieve a desired tension in the screw complex. When clinicians apply torque by hand, errors of 15% to 48% may be expected.^{6,9} Further, the amount of torque, and therefore the amount of preload, is dependent on the experience level of the operator.^{9,21} It has been stated that inexperienced operators tend to undertorque screws, while experienced operators tend to overtorque them.^{7,9,10,21,25} Because there is a wide variation in the ability of clinicians to deliver manufacture-recommended torque tightening levels through handdrivers, the torque limiting devices are necessary to ensure consistency in tightening implant components.¹⁰ However, although the clinical use of these devices is recommended, the torque controllers may produce some substantial variations in torque delivery being in clinical service.^{4,7,9,10,13,26} Therefore, to reduce any potential for inaccurate torque application, the clinician should use a torque controller device that is annually calibrated.

One of the limitations of this in vitro study is the calibration accuracy of $\pm 2\%$ of the Tohnichi, an error of 0.5 N-cm could be expected on a 25 N-cm; however, this value is low and would have been the same for all tested devices. In addition, a very little information was available regarding the number of times each device had been sterilized. However, the only consistent information was that each wrench was used 15 to 20 times weekly and sterilized prior to each in vivo use. With the lack of detailed information, no statistics could be run on torque accuracy versus the number of sterilization cycles.

Within the limitations of this study, the best results were achieved with the Frialit torque driver. This study was significant in that it measured the respective target torque values and demonstrated that variations in expected and actual values can occur over variable amounts of time. The results obtained with the Friadent and Straumann torque controller were the best among the others. Until a clinically acceptable safety zone around the target torque is established, the torque limiting devices should be improved. In addition, the clinical torque controllers should be annually recalibrated to ensure optimal output.

CONCLUSION

This study evaluated the accuracy of different implant systems torque wrenches in delivering their target torque values after one year in clinical service. Based on the results of this investigation, the torque output of each individual device deviated in varying degrees from respective target torque values.

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