Comparison of the torque stability of Implant Torque Controllers

Dae-Gon Kim, Lee-Ra Cho, Chan-Jin Park

Department of Prosthodontics, College of Dentistry, Kangnung-Wonju National University

Corresponding Author

Prof. Chan-Jin Park
Department of Prosthodontics and Research Institute of Oral Science.
Kangnung-Wonju National University, 1 Gangneungdaehangno, Gangneung, Gangwon-do, 210-702, Korea

E-mail : doctorcj@nukw.ac.kr

• Abstract

Tightening of the screws in implant restorations should be accurate and precise. If applied torque is too low, screw loosening would be occurred. With too high torque, the screw fracture might take place. Various torque generating devices are developed and employed to apply a proper torque. The purpose of this investigation was to determine and compare the accuracy of the torque controllers.

In this study, 4 types of torque controllers were used; electronic torque controller, torque limiting device, torque indicating device and contra angle torque driver. Digital torque gauge was employed to measure the de-torque value. Thirty cycles of tightening and loosening were done with each torque controller.

All implant torque controllers have shown slight errors and deviations. The torque liming device exhibited the most accurate data. No significant difference was found among the mean de-torque values of the electronic torque controller, torque indicating device and contra angle torque driver.

In the limitation of this study, it would be recommended that the implant torque controllers should be checked whether uniformed and precise torque can be generated and a measuring error should be corrected.

• Key word : de-torque, torque, torque controllers

• J Kor Dent Sci. 2009; 2(1) : 19 - 27

Introduction

Implant prostheses are available in 2 designs: screw- or cement-retained. The advantage of the screw-retained prosthesis is that it can be easily removed and reattached by the clinician and can be fabricated in areas with restricted space. The prosthesis can easily be repaired but it is hard to design contact points because of the screw hole on the occlusal surface. Loading along the long axis of the implant is problematic and the screw is not as aesthetically pleasing as the cement-retained type. Loosening can also occur.[1] The occlusal stability of a cement- retained implant is superior and loading can easily be given along the long axis of the implant. The cement-retained prosthesis is relatively easy to fabricate and is quite aesthetic but it is difficult to apply in areas with restricted intermaxillary space. Removal of the subgingival cement the prosthesis repair are difficult.

Regardless of the implant type, the fixture and upper structure is designed to be connected by a screw. This design allows easy removal and functions as a stress breaker when loaded. However, loosening of the screw, screw fracture, and screw abrasion may occur.

When reviewing the literature for screw loosening frequency, Jemt et al.[2] in 1991 reported that during 1 year after implant installation, 26% of gold retention screws and 43% of fixture screws were loosened; but as the fixture component was improved and by using an implant torque controller, loosening occurred much less frequently. Priest[3] in 1999 reported 7.1% screw loosening in 10 years after implant installation and in 2008 Jung et al.[4] reported 12.7% during 5 years after implant installation.

The cause of screw loosening and fracture has been observed to be related to mechanical tolerance[5], screw mateiral[6,7], fatigue resistance of the metal[8], micromovement on functioning, occlusal force out of the long axis[9,10], applied torque and preloading[11], elasticity and settling effect of the alveolar bone[12]. The settling effect is a phenomenon in which two surfaces with different micro-roughness are facing each other and the space is narrowed by abrasion caused by the rougher surface.[12,13]

Screw loosening occurs in two steps. First, an external force such as masticatory force applied to the screw connection area causes preloading and decreases the tensile strength, which results in sliding between spirals. Secondarily, preloading decreases below the critical point and external forces and vibration cause rotation of the spirals resulting in screw loosening.[14] Screw loosening such as this may cause screw fracture, prosthesis fracture, loss of osseointegration and implant fixture fracture. Screw loosening is caused by external reasons such as inadequate implant positioning, occlusal relationship, crown configuration, excessive masticatory force, insufficient tightening torque, and incongruity between fixture and implant, and internal reasons such as loss of preloading caused by decrease in tensile strength of the screw itself.[15,16]

Jörnéus et al.[17] reported that the main reason of screw loosening is inadequate tightening force. When the tightening force is less than adequate, screw loosening occurs and screw fracture occurs in the opposite situation. When the screw is tightened manually inadequate rotatory force is applied, resulting in inadequate preloading, which allows the screw to more easily loosen than a screw tightened with adequate torque. Jaarda et al.[18] reported that the primary reason for screw loosening is inadequate torque and loss of preloading. When the fixture screw is manually locked, an error of 15-48% may occur, thus to gain the adequate torque recommended by the manufacturer, it is better to use a mechanical torque controller[19]. Goheen and Binon[20,21] reported that a manual torque controller generally cannot produce a torque bigger than 20Ncm, and Delinges et al.[22] reported that there was a difference in the torque applied by men and women underlining the importance of using a mechanical torque controller.

To prevent screw loosening along the screw length of the fixture, configuration of the spiral and groove, position of the spiral and numbers may be modified or the surface roughness of the screw may be changed.[23] Also, the manual fitness of the prosthesis may be enhanced or the number of implants may be increased, the occlusal interference can be removed and the occlusal surface decreased, the contact surface with proximal teeth may be increased but above all, a torque controller should be applied to gain the torque recommended by the manufacturer.[24]

Implant manufacture companies have developed various types of torque controllers and they are being used to apply adequate torque to implants. The electronic torque controller applies rotatory force by a mechanical torque producer, while the torque limiting device is designed so that the anterior part of the handle bends when the torque exceeds the prescribed level. The torque indicating device has a scale so the operator can set the amount of tightening force. The contra-angle torque device is able to attach controllers that

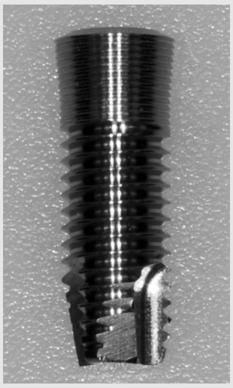


Fig. 1. Implant fixture

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

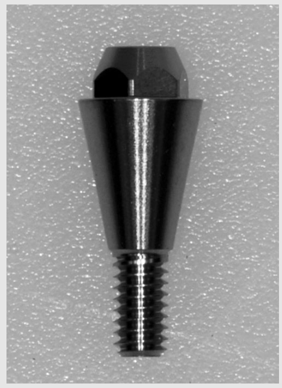


Fig. 2. Implant abutment

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

have fixed or controllable force to the contra-angle hand piece.

But many studies report gaps between the force recommended by the manufacturer and the actual torque applied by the torque controller.[25)] Gutierrez et al.[26)] reported an error rate of 17.0%~58.6% depending on the service life of the controller. Standlee et al.[27,28)] reported that Nobel Biocare torque controller has an error rate of 8.0%~41.0%. The ITI and DynaTorq ITL torque controllers have an error rate around 10% while Dellinges et al.[29)] reported that the DynaTorq ITL torque controller delivers a reliable result.

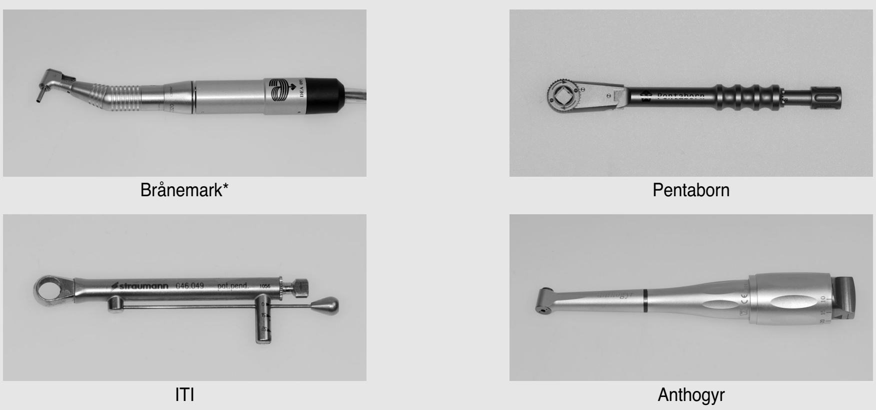
Various types of torque controllers are currently being used and differing error rates are being reported depending on the type of torque controllers. In this study, 4 types of torque controllers were used to measure the torque and de-torque value and compare it with the manufacturer's recommended value. Differences between actual forces applied by the controller and recommended values were examined to compare and analyze the accuracy of the torque controllers.

Material and Method

1. Study Material

1) Implant fixture (Fig. 1)

Twenty fixtures of Pentaborn (Mediscitec, Incheon, Korea) implant with 4.0mm diameter and 12.0mm length were used.



(* Brånemark : Nobel Biocare Electronic torque controller)
Fig. 3. Torque generating devices.

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

2) Implant abutment (Fig. 2)

Twenty abutments of Pentaborn (Mediscitec, Incheon, Korea) implant with 4.5mm diameter and 3.0mm gingival height screw abutments were used.

3) Torque Controllers (Fig. 3)

One electronic torque controller and three manual torque controllers were used to apply the force recommended by the manufacturer to connect the implant fixture and abutment.

① Electronic torque controller (Brånemark system DEA020 Torque Controller, Nobel Biocare AB, Göteborg, Sweden)

② Torque limiting device (Pentaborn, Mediscitec, Incheon, Korea)

③ Torque indicating device (Straumann, Basel, Swiss)

④ Contra-angle torque device (Torq Control Ref. 15000, Anthogyr, Sallanches, France)

2. Study Method

1) Specimen fabrication

① Implant fixation

To fabricate resin blocks of identical shape, a template was made with silicone impression material (EXAFINE PUTTY TYPE, GC Corporation, Tokyo, Japan). The implant was placed vertical to the ground on a dental surveyor and the implant fixture spirals were locked with PMMA self-curing resin (Ortho-jet. Lang Dental Manufacturing Co., Inc. Wheeling, U.S.A.). (Fig. 4)

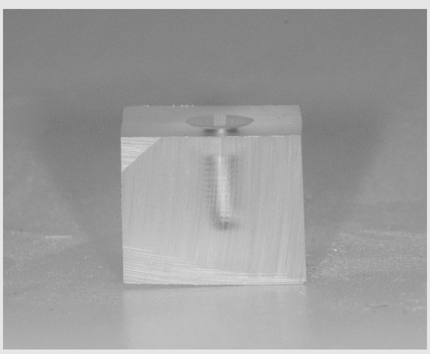


Fig. 4. Resin block specimen

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

The resin block was shaped into a 20mm × 20mm × 20mm regular hexahedron using a cutter with a diamond blade and abrasor (Exakt-Cutting Grinding System Apparatebbau, Norderstedt, Germany) then cut and ground with number 600, 800, and 1000 sandpaper and finally cleansed in a ultrasound washer for one minute.

② Resin block fixation

To repeatedly attach and detach the fixture and abutment, the specimen was placed parallel to the ground using a custom made device. (Fig. 5)

Fig. 5. Specimen-holding apparatus

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

2) Connecting the fixture and abutment

Each abutment was connected to the fixture. One type of electronic torque controller and three types of manual torque controllers were used with a force of 20 Ncm to connect the abutment.

Fig. 6. Digital torque gauge

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

3) Repeated tightening and loosening of the abutment and measurement of each de-torque value (Fig. 6, 7)

The de-torque value of abutments which were attached using 4 types of different torque controllers were measured with a custom device and torque measuring instrument (MGT12, Mark-10 Inc., New York, USA). A 10 second interval was given between tightening and loosening the abutment screw and this was repeated 30 times for de-torque value measurement of each specimen. Five implant specimens were prepared for each torque controller and the abutment screw tightening and loosening procedure was repeated.

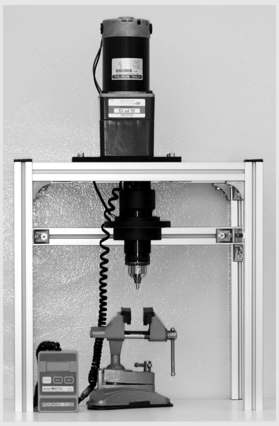


Fig. 7. Custom made Torque gauge

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

3. Statistical Analysis

The SPSS 14.0K for Windows program was used to compare the de-torque value according to each torque controller. Repeated Measured ANOVA was conducted at 95% significance level to evaluate the relationship among each torque controller, measurement cycle, specimen and measurement cycle in each group. Post-hoc studies were done to evaluate the difference between groups with the Tukey test.

Results

The de-torque value of each torque controller from different manufacturers are presented in tables I and II. When the torque value is compared to the standard tightening torque of 20 Ncm, the error rate of each company was Brånemark 9.5%, Pentaborn 2.6%, ITI 7.1% and Anthogyr 12.5%, which shows that comparing the mean values the error rate of Pentaborn was lowest and Anthogyr was highest. The maximum measurement value was Brånemark 17.0%, Pentaborn 23.0%, ITI 5.0% and Anthogyr 12.5% and the minimum measurement value was Brånemark 24.0%, Pentaborn 14.5%, ITI 15.0% and Anthogyr 25.0%. At the maximum measurement value, the error rate of ITI was the lowest and Pentaborn was the highest while at the minimum measurement value the error rate of Pentaborn was the lowest and Anthogyr was the highest.

The repeated measured ANOVA results showed that in intra-subject effect analysis there was a difference according to repetition cycle and the measured value was affected by repetition number and torque controller. Inter-subject effect analysis results showed that the measured value was affected by the torque controller. (Tables Ⅲ, Ⅳ)

Table Ⅰ. De-torque values (Mean±SD Ncm)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Brånemark	19.13±1.41	17.44±1.82	17.70±2.13	17.86±1.37	18.44±1.47
Pentaborn	19.87±1.42	20.05±1.14	20.47±1.72	21.50±1.88	20.66±1.59
ITI	18.51±0.78	17.74±0.66	19.02±1.24	18.79±0.79	18.86±0.94
Anthogyr	18.16±1.37	18.48±1.36	16.91±1.90	18.24±1.50	18.61±1.51

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

Table Ⅱ. Mean, maximum and minimum de-torque values (Ncm)

	Mean(Error rate)	Max(Error rate)	Min(Error rate)
Brånemark	18.11(9.5%)	23.40(17.0%)	15.20(24.0%)
Pentaborn	20.51(2.6%)	24.60(23.0%)	17.10(14.5%)
ITI	18.58(7.1%)	21.00(5.0%)	17.00(15.0%)
Anthogyr	18.08(9.6%)	22.50(12.5%)	15.00(25.0%)

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

The multiple regression analysis with post-hoc studies using the Tukey test show that there were no statistically significant differences among torque controllers from ITI, Brånemark and Anthogyr but the torque controller of Pentaborn showed statistically significant differences in accuracy with the other three types of torque controllers. (Table Ⅴ) The Pentaborn torque controller demonstrated the best results compared to the standard value; and ITI, Brånemark and Anthogyr were next in order of similarity

Table Ⅲ. Tests of Within-Subjects Effects

Source		Type Ⅲ Sum of Squares	df	Mean Square	F	Sig.
Number of measurements	Sphericity Assumed	860.222	29	29.663	54.910	.000
	Greenhouse-Geisser	860.222	6.622	129.898	54.910	.000
	Huynh-Feldt	860.222	13.910	61.841	54.910	.000
	Lower-bound	860.222	1.000	860.222	54.910	.000
Number of measurements	Sphericity Assumed	111.785	87	1.285	2.379	.000
* Torque controllers	Greenhouse-Geisser	111.785	19.867	5.627	2.379	.002
	Huynh-Feldt	111.785	41.731	2.679	2.379	.000
	Lower-bound	111.785	3.000	37.262	2.379	.108
Error	Sphericity Assumed	250.656	464	.540		
(Number of measurements)	Greenhouse-Geisser	250.656	105.957	2.366		
	Huynh-Feldt	250.656	222.564	1.126		
	Lower-bound	250.656	16.000	15.666		

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

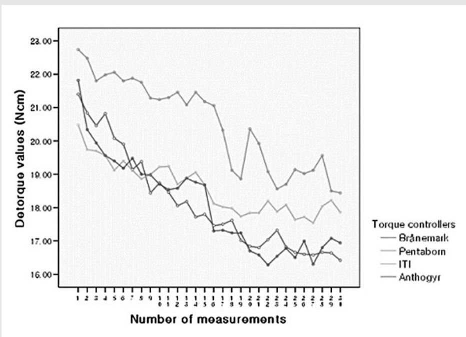


Fig. 8. Changes of de-torque values

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

Table Ⅳ. Tests of Between-Subjects Effects

Source	Type Ⅲ Sum of Squares	df	Mean Square	F	Sig.
Sample	212549.3	1	212549.3	17890.190	.000
Torque controllers	592.938	3	197.646	16.636	.000
Error	190.092	16	11.881		

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

Table Ⅴ. Post Hoc Multiple Comparisons

	Torque controllers	N	Groups	
			1	2
Tukey HSDa,b,c	Pentaborn	5	20.5087	
	ITI	5		18.5827
	Brånemark	5		18.1133
	Anthogyr	5		18.0813
	Sig.		1.000	.600

Chan-Jin Park et al : Comparison of the torque stability of Implant Torque Controllers. J Kor Dent Sci 2009.

with the standard.

By presenting the mean value of each specimen according to repetition cycle in a graph that reveals the measurement value of each torque controller, it shows that the initial de-torque value is generally higher than standard and the value was uniform up to 15 cycles for Pentaborn and Branemark and then the value drastically decreases for every controller after about 15 to 20 repetitions. There is a general tendency of de-torque values decreasing as the number of repetitions increases. (Fig. 8)

Discussion

Many studies have reported a considerable difference between the actual value applied by a torque controller and the manufacturer's recommended torque. Standlee et al.[27,28] repeated measurements 10 times using 6 torque controllers from Nobel Biocare, 5 from ITI and 6 DynaTorq ITL torque controllers showing that the Nobel Biocare torque controller showed the largest error rate of 8.0% to 41.0% while the ITI and DynaTorq ITL torque controller showed errors within 10% of the adequate value. Dellinges et al.[19,22] reported that the DynaTorq ITL torque controller showed a reliably low error rate before sterilization and the error rate generally rose after sterilization. At 10Ncm, the overall error rate before and after sterilization showed no statistically significant difference. Inaccurate and inadequate torque can be caused by frequency of controller use, foreign substances in the device, and corrosion of the spring.

In this study the comparison between the standard value

(20Ncm) and the error rate of de-torque values of torque controllers from different manufacturers show that the error rate of Pentaborn is the lowest and that of Anthogyr is the highest. The torque controller must maintain adequate torque value on average after repeated use intraorally. When the results are considered on the torque limiting devices' accuracy, the Pentaborn is considered superior to the other three types of torque controllers.

When the de-torque value of each torque controller according to repeated measurements were analyzed. After 30 repeated measurements, the Pentaborn torque controller showed values closest to the standard value, with ITI, Brånemark and Anthogyr next in order. There were no statistically significant differences among the ITI, Brånemark and Anthogyr.

When comparing the accuracy of different torque controller shapes, the torque limiting device by Pentaborn showed superior results compared to the other torque controllers. Since the handle of a torque limiting device bends when the applied torque exceeds a preset value, except for cases of aging, corrosion, and abrasion of the internal device spring, the torque can be stably maintained at a certain value. Torque indicating devices are designed so the torque is controlled by pulling, so it may be affected by service life or aging of the spring. Above all, the amount of force and application rate by the user may lead to a difference in torque amount accuracy. In the case of the contra-angle torque device, an error was observed to be produced by slight impact and diversion occurring by a movement at the abutment attachment area when the handle is rotated. The electronic torque controller was expected to show the most stable de-torque value but the reason for its low accuracy may be the larger range of load application compared to the value less of than 35Ncm for the manual torque controllers.

The mean value of each specimen according to repetition cycle is presented in a graph in relation to the measurement value of each torque controller. The graph shows that the initial de-torque value is generally higher than standard. This can be explained by the increase of preloading caused by settling effect. And the fixture-abutment connection type used in this study was internal, which compared to the external type that is maintained only by a screw, is strongly sustained by the screw contact area and also by contact between the long internal walls of conical configuration. This may have resulted in the higher de-torque value.

This study shows that the initial de-torque value remained uniform for up to 15 cycles for the Pentaborn and ITI and then the value drastically decreases for every controller after about 15 to 20 repetitions. There is a general tendency for the de-torque value to decrease when the number of repetitions increases. These results are consistent with those of previous studies. Gutierrez et al.[26] reported that when 35 torque controllers including 4 types, DynaTorq ITL, Steri-Oss, Lifecore, and Dentsply torque controller, were used for 1 to 42 months, the error rate ranged from 17% to 58.6%. The results show that the relation between usage duration, sterilization frequency, and torque controller did not show a statistical significance; but with corrosion of the internal device spring and aging and abrasion of the spring, errors up to 455.0% were found. In another study on the accuracy of torque controller and sterilization frequency, ?ehreli et al.[29] compared the accuracy of 15 unused ITI torque controllers and after 50 to 200 uses, 500 to 1000 uses. Accuracy was maintained but there was a tendency of the measured value to decrease as the usage frequency increased.

There is a difference in standard value but the de-torque value remained uniform for up to 15 cycles for the Pentaborn and ITI units. Considering the importance of maintaining a certain level after repeated use, these two torque controllers will be able to show superior clinical results by decreasing the difference between standard value and actual torque through regular checkups.

Every torque controller showed a drastic decrease of de-torque value after 15 to 20 uses. Considering the fact that except for the first year, 1-2 applications of torque are made annually. It is recommended that the tightening and loosening procedure of the abutment screw intraorally be repeated 15 times. The decrease in preload caused by the decrease in coefficient of friction resulting from the friction between the two facing surfaces after repeated tightening and loosening of the screw is considered to be the reason why the de-torque value decreases after repeated tightening of the abutment screw.[30]

The limitation of this study is that the measurements were conducted on a laboratory model and not in the true intraoral environment, which may cause differences from the actual measurement values. Also, the torque controllers used in this experiment had been used in the clinic for a short while and the specific duration and number of uses for each controller are unable to be verified. This may contribute to errors in the results so additional experiments after grouping every torque controller according to usage duration and number could result in a more objective comparison. The specimen number for each standard measurement value was 5 and the repeated measurement number was limited to 30 times, so it is necessary to diversify the standard measurement value for each implant system and increase the specimen and measurement number.

Conclusion

This study was designed to analyze the exactness and consistent readings of torque controllers from 4 different manufacturers and seek statistically significant differences between each device.

The below conclusions have been drawn.

1. From the comparison of the measured mean, maximum and minimum value, the Pentaborn torque controller had superior accuracy compared to the other three types of torque controllers.
2. When the measured values were analyzed after repeated use, the Pentaborn torque controller had the closest value to standard and ITI, Brånemark, and Anthogyr were next in order. But there were no statistically significant differences among ITI, Brånemark, and Anthogyr.
3. When comparing the accuracy according to torque controller type, a torque limiting device such as Pentaborn showed superior results but there were no statistically significant differences in accuracy among the electronic torque controller of Brånemark, the torque indicating device of ITI, and the contra-angle torque device of Anthogyr.

According to the results of this study a gap exists between the actual tightening forces applied by various torque controllers. This implies that it is difficult to apply exact tightening force so the clinician must use regular checkups and adjustments to his or her torque controller to obtain stable, accurate force values.

References

1. Misch CE. Contemporary Implant Dentistry. 2nd edn, pp549-93, St Louis, 2000, Mosby.
2. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991;6(3):270-6.
3. Priest G. Single-tooth implants and their role in preserving remaining teeth: a 10-year survival study. Int J Oral Maxillofac Implants 1999;14(2):181-8.
4. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP. A systematic review of the 5-year survival and complication rates of implant-supported single crowns. Clin Oral Implants Res 2008;19(2):119-30.
5. Khraisat A, Hashimoto A, Nomura S, Miyakawa O. Effect of lateral cyclic loading on abutment screw loosening of an external hexagon implant system. J Prosthet Dent 2004;91(4):326-34.
6. Breeding LC, Dixon DL, Nelson EW, Tietge JD. Torque required to loosen single-tooth implant abutment screws before and after simulated function. Int J Prosthodont 1993;6(5):435-9.
7. Jaarda MJ, Razzoog ME, Gratton DG. Comparison of "look-alike" implant prosthetic retaining screws. J Prosthodont 1995;4(1):23-7.
8. Patterson EA, Johns RB. Theoretical analysis of the fatigue life of fixture screws in osseointegrated dental implants. Int J Oral Maxillofac Implants 1992;7(1):26-33.
10. Rangert B, Jemt T, Jörneus L. Forces and moments on Branemark implants. Int J Oral Maxillofac Implants 1989;4(3):241-7. Weinberg LA, Kruger B. A comparison of implant/prosthesis loading with four clinical variables. Int J Prosthodont 1995;8(5):421-33.
11. Jaarda MJ, Razzoog ME, Gratton DG. Effect of preload torque on the ultimate tensile strength of implant prosthetic retaining screws. Implant Dent 1994;3(1):17-21.
12. Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10(5):529-36.
13. Winkler S, Ring K, Ring JD, Boberick KG. Implant screw mechanics and the settling effect: overview. J Oral Implantol 2003;29(5):242-5.
14. Bickford JH. An introduction to the design and behavior of bolted joints. Marcel Dekker, New York 1995;515-64.
15. Binon PP. The external hexagonal interface and screw-joint stability: A primer on threaded fasteners in implant dentistry. Quint Dent Tech 2000;23:91-104.
16. McGlumphy EA, Mendel DA, Holloway JA. Implant screw mechanics. Dent Clin North Am 1998;42(1):71-89.
17. Jörnéus L, Jemt T, Carlsson L. Loads and designs of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7(3):353-9.
18. Jaarda MJ, Razzoog ME, Gratton DG. Effect of preload torque on the ultimate tensile strength of implant prosthetic retaining screws. Implant Dent 1994;3(1):17-21.
19. Dellinges M, Curtis D. Effects of infection control procedures on the accuracy of a new mechanical torque wrench system for implant restorations. J Prosthet Dent 1996;75(1):93-8.
20. Goheen KL, Vermilyea SG, Vossoughi J, Agar JR. Torque generated by handheld screwdrivers and mechanical torquing devices for osseointegrated implants. Int J Oral Maxillofac Implants. 1994;9(2):149-55.

References

21. Binon PP. Evaluation of the effectiveness of a technique to prevent screw loosening. J Prosthet Dent 1998;79(4):430-2.

22. Dellinges MA, Tebrock OC. A measurement of torque values obtained with hand-held drivers in a simulated clinical setting. J Prosthodont 1993;2(4):212-4.

23. Martin WC, Woody RD, Miller BH, Miller AW. Implant abutment screw rotations and preloads for four different screw materials and surfaces. J Prosthet Dent 2001;86(1):24-32.

24. Lang LA, May KB, Wang RF. The effect of the use of a counter-torque device on the abutment-implant complex. J Prosthet Dent 1999;81(4):411-7.

25. Mitrani R, Nicholls JI, Phillips KM, Ma T. Accuracy of electronic implant torque controllers following time in clinical service. Int J Oral Maxillofac Implants 2001;16(3):394-9.

26. Gutierrez J, Nicholls JI, Libman WJ, Butson TJ. Accuracy of the implant torque wrench following time in clinical service. Int J Prosthodont 1997;10(6):562-7.

27. Standlee JP, Caputo AA, Chwu MY, Sun TT. Accuracy of mechanical torque-limiting devices for implants. Int J Oral Maxillofac Implants 2002;17(2):220-4.

28. Standlee JP, Caputo AA. Accuracy of an electric torque-limiting device for implants. Int J Oral Maxillofac Implants 1999;14(2):278-81.

29. çehreli MC, Akça K, Tönük E. Accuracy of a manual torque application device for morse-taper implants: a technical note. Int J Oral Maxillofac Implants. 2004;19(5):743-8.

30. Burguete RL, Johns RB, King T, Patterson EA. Tightening characteristics for screwed joints in osseointegrated dental implants. J Prosthet Dent. 1994;71(6):592-9.