The Accuracy of Various Torque Wrenches Used in Dental Implant Systems

Hamidreza Rajatihaghi[1], Jalil Ghanbarzadeh[1], Neda Daneshsani[2], Rasul Sahebalam[3], Mohammadreza Nakhaee[1]

[1] Dental Research Center, Department of Prosthodontics, Faculty of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran
[2] Faculty of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran
[3] Dental Research Center, Department of Pediatric Dentistry, Faculty of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

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Abstract

Introduction: The purpose of this study was to compare the accuracy of the torque wrenches used in different dental implant systems. **Methods:** We evaluated 42 torque wrenches used in different dental clinics in Mashhad, Iran, using a digital torque meter (Mark 10). High (25, 30 and 35 N·cm) and low (15 N·cm) levels of torque were examined. Ten tests were performed on each wrench, and the mean value was considered as the real torque of the instrument. Different characteristics (Model (spring or friction), System, Duration of use, Sterilization, Calibration) of each wrench were also recorded. The difference between the torque applied by the instrument and the target torque required was calculated numerically and as a percentage. A one-way ANOVA and Student's *t*-test were used for statistical analysis. **Results:** There was a significant difference between the error at higher torques in the spring wrenches compared with the friction wrenches (P<0.05). At higher torques, an error greater than 10% was more common in the friction wrenches (29.4%) than in the spring wrenches (4.3%). No significant differences were observed regarding the duration instruments usage and the mean numerical error at high and low torque. In the wrenches that had been used for more than three years, 21.1% of samples showed an error of more than 10%, compared with 9.5% in wrenches that had been used for less than three years (P=0.39). At higher torques the Straumann system produced the least error and the Biohorizon system produced the greatest error which was significantly greater than the other systems (P<0.05). **Conclusion:** Our results indicate that spring wrenches produce more accurate results than friction wrenches; however, friction wrenches are more reliable at lower torques than higher torques. The length of time in use and sterilization of torque wrenches does not affect the function of the instruments significantly. The precision of the instrument system used is also important.

Key Words: Implant, torque, torque wrench.

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Introduction

Using implants for the treatment of completely or partially edentulous patients improves chewing function and patients' quality of life in comparison with removable or teeth-supported fixed prostheses (1). However, as with other treatment methods in dentistry, implants can have complications and problems (2).

The connection between the abutment and fixture in the implant complex is a screw joint that needs to form a stable connection in order to function effectively (3). The forces applied to the screw joint can be divided into two types. The first type is a clamping force that tends to keep the parts of the connection together, while the second type are separating forces that tends to separate the parts of the screw Joint (4).

It has been shown that in terms of magnitude, the preload occurring in the screw is equal to the clamping force (3). However, the separating force decreases the preload in the screw via slippage between the screw and the bore's threads inside the fixture (5). The incidence of loosening of the abutment screw in all dental prosthetic implants has been reported to be 6% (2).

The preload in screws is proportional to the applied torque, which can be expressed as Torque = Preload × A (Constant). The variable of torque is under the control of the clinician (3). Application of too Low level of torque may lead to screw fatigue and screw loosening, while too high level of torque may remove the screw's threads (stripping) or even break the screw (6).

The methods available for applying torque to the screw joint of an implant complex include using manual, mechanical or electronic torque wrenches. In the first stage of screw tightening the most simple and common method used is the manual tightening; however, the need for tactile sensitivity is high and the torque applied can vary greatly. In addition, the torque applied by this method is mostly low; therefore this method is not recommended for final screw tightening (7).

Electronic wrenches used in dental implants are calibrated to apply a certain torque magnitude. The Mechanical tools come in various designs that apply the desired torque through a release mechanism or via the scales on the tool (7).

Various studies have been done on the accuracy of these tools in comparison with the manufacturers' claims and also on the effects of sterilization and the length of time in use. In a study by Santos et al. (8), some torque wrenches were shown to not have sufficient accuracy for torque application.

In an investigation of accuracy of 17 torque wrenches, 9 of which were toggle-type wrenches and 8 of which were beam wrenches, McCracken et al. (9) concluded that calibration is especially necessary for toggle-type wrenches, and that the slow (4 sec) torque application method is more accurate. The study also concluded that beam wrenches seem to require less maintenance (9).

Vallee et al. (7) also performed a study investigating the accuracy of torque-applying mechanical tools. They investigated two different designs, friction-style and spring-style wrenches and concluded that spring-style tools were significantly more accurate than friction –style ones.

In an investigation of the torque applied by old and new Straumann tools, Cehreli et al. (10) concluded that the torque applied by these tools has less variability and length of use does not have a significant effect on their accuracy. Similarly, Standlee et al. (11) investigated three different types of mechanical tools and showed that Straumann tools had sufficient accuracy for applying the recommended torque. Gutierrez et al. (12) conducted a study that compared the accuracy of several torque wrench models following time in clinical service. The results of the study showed that although the torque applied by most tools is near to the target value, some tools show a significant difference from the target value. In addition, no relationship was observed between the age, the amount of sterilization, and the torque applied by the tool. The researchers who performed the study recommended that wrenches be calibrated annually. A study of manual, electronic and mechanical wrenches by Goheen et al. (13) showed that using manual force and a hand screw driver produced lower levels of torque than the desired torque and that mechanical torque wrenches have a lower variation than electronic ones.

The purpose of this study was to compare the accuracy of the torque wrenches (in view of spring/friction, duration in use, implant system, amount of torque applied) that were in clinical service more than 3 months. The null hypothesis was that there would be no differences in implants system and amount of torque applied but duration in use have negative effect on accuracy.

Materials and Methods

In this study, we attempted to test the majority of torque wrenches used in dental clinics within Mashhad. Overall, a total of 42 torque wrenches (from 15 clinical centers) were tested in various systems, which was deemed sufficient according to the number tested in similar studies (Table 1).

Table 1. Types and number of wrenches tested

System	Number	Model	Target Torque (N.cm)	Average Duration
Straumann	9	Spring	15-35	5.8
Dio	11	Spring	15-35	3.5
Astra	6	Frictional	15-25	5.4
Biohorizon	5	Frictional	15-30	4.7
Dentis	1	Spring	15-35	7
3i	1	Spring	15-25	2
Implantium	2	Frictional	15-35	2.5
Bego	2	Frictional	15-25	3.5
SPI	2	Spring	15-35	2
Ihde	3	Frictional	15-30	3

The torque wrenches tested were between 11 months and 10 years old. All specimens, with the exception of three wrenches, were sterilized in autoclave and the number of sterilization cycles was twice a week for most wrenches. No wrench had a calibration history. The wrenches were compared in two different groups (friction and spring) (Fig. 1). In addition, they were divided into two groups based on the duration of use: more than three years of use and less than three years of use.

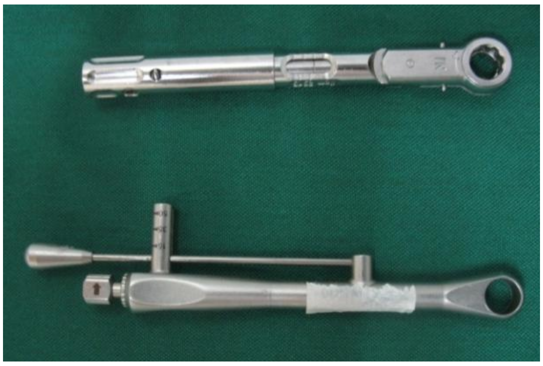

Figure 1. Examples of a friction wrench (above) and a spring wrench (below)

Ten systems with different target torques were tested. The target torque was tested 10 times for each device and the average recorded as the device torque. Out of the 42 wrenches, 24 were spring and 18 were friction devices. An electronic torque measurement device, the Digital Force/Torque Indicator, Mark-10 Model BGI (Mark-10 Corporation, USA) with accuracy of ± 0.10 N·cm was used to perform the tests (Fig. 2).

Figure 2. The Mark-10 electronic torque measurement device

The torque measurement device had a three-jaw chuck design with the ability to hold the hand driver of each system. Then a wrench was applied to the driver. While an operator was responsible for applying torque to the driver based on the recommended value of each system, another one read the maximum torque recorded in the device's digital display. The speed of applying torque was slow in four seconds.

Overall, three classifications were used for the specimens: 1) type, spring or friction; 2) duration of use, less or more than three years; and 3) torque wrench system. The mean torque error and standard deviation of each of the three above-mentioned classifications was calculated as a raw number (DIFF H, L) (N·cm) and as the percentage error at high and low torques (H, L PERCENT). High torques were 35, 30, 25 N.cm and low torque was 15 N.cm. According to the fact that a 10% torque error is used as a cut-off point for continued use or retirement of a torque wrench in the clinic, the three classifications were investigated based on a 10%

error index and the differences were examined using a Chi-square test.

In addition, a *t*-test was used for investigating the differences between the spring (S) and friction (F) wrenches and usage time (less and more than 3 years). A one-way ANOVA was performed to evaluate the statistically significant differences between the various systems. When the P-value indicated statistical significance a Tukey test was performed using SPSS software. P-value of less than 0.05 was considered to be statistically significant.

Results

The results were examined in three different ways. The first division of the results was based on the type of torque wrench, spring or frictional. The average error for spring wrenches at high (35, 30, 25 N·cm) and low (15 N·cm) torques was 1.14 ± 1.1 N·cm and 0.58 ± 0.51 N·cm, respectively. In the friction wrenches, the average error from the target torque at high (25, 30, 35 N·cm) and low (15 N·cm) torques was 2 ± 1.5 N·cm and 1 ± 0.95 N·cm, respectively. Based on these results, it seems that friction wrenches have a lower accuracy than spring wrenches (Fig. 3). In addition, there was more error in the application of high torques than low ones.

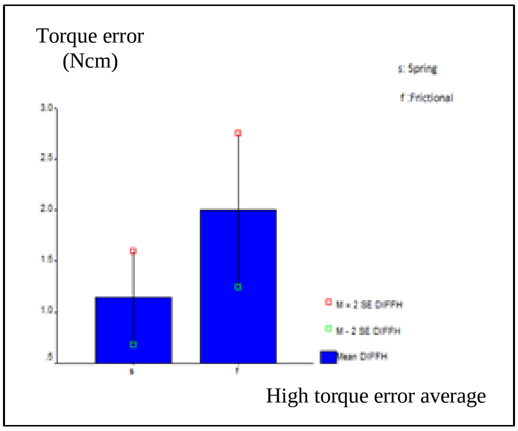

Figure 3. Torque error at high torques for spring and friction wrenches

The second division of the results was based on the duration of use of the wrenches, which were divided into two groups, those that had been in use for less than three years and those had been used for more than three years (Table 2). A total of 22 wrenches had been used for more than three years and 20 for less than three years. The mean error in wrenches that had been used for less than three years at high and low torques was 1.15±1.03 N·cm and 0.61±0.54 N·cm, respectively; while in wrenches that had been used for more than three years the mean error was 1.89±1 N·cm and 0.83±0.83 N·cm, respectively. These numbers show that the mean error in wrenches that had been used for more than three years was slightly more, but the differences were not statistically significant.

The difference between the number of total torque wrenches and the number in above table is related to six torque wrenches which have only high torque and one wrench which has only low torque.

Based on the duration of use of the wrenches, at high torques two (9.1%) of the wrenches that had been used for less than three years and four (21.1%) of the wrenches that had been used for more than three years had errors of more than 10% but this was not a significant difference (P=0.39). In addition, at low torques, one (5.6%) of each of the groups of wrenches had an error of more than 10% (P=1.000).

The third division of the wrenches was based on the manufacturer, of which there were 10. The four most popular systems were Straumann, Biohorizon, Dio, Astra with more than five wrenches in each of these groups (Table 3).

From five Biohorizon torque wrenches four only have high torque and one only has low torque. The results of a one-way ANOVA test indicated that there was a significant difference between the four groups at high torques. The data shown in Table 3 shows that the mean error at high torques was highest in the Biohorizon group followed by the Astra, Dio and Straumann systems, while at low torques the highest error was observed in the Astra group. The use of Tukey test showed that the difference between the Biohorizon group and the other three groups was significant at high torques, but there were no significant differences among the Dio, Straumann, and Astra groups.

The highest percentage error recorded at high torques was 18% for a friction device in a Biohorizon system with an eight-year history that was sterilized by autoclave. The lowest percentage error at high torques was 0% for two wrenches, a friction wrench made by Astra and a spring wrench made by Straumann, both of which had a one-year history and were sterilized by autoclave. In the 15 N·cm torque group, the highest percentage error was recorded as 25.4% in a friction wrench in an Astra system with a seven-year usage history. The lowest percentage error at 15 N·cm (0%) was reported for an Straumann wrench with a 10-year history.

Table 2. Results of a *t*-test comparing the mean error between wrenches used for less than three years and those used for more than three years

Duration of Use	Number	Mean Error	Standard Deviation	P-value
DIFFH				
≤3 years	22	1.15	1.04	**0.083**
>3 years	19	1.89	1.61	
DIFFL				
≤3 years	18	0.62	0.54	**0.364**
>3 years	18	0.83	0.84	
HPERCENT				
≤3 years	22	3.78	3.34	**0.138**
>3 years	19	5.96	5.35	
LPERCENT				
≤3 years	18	4.08	3.61	**0.352**
>3 years	18	5.56	5.60	

Table 3. A comparison of the wrenches belonging to the four most popular manufacturers

System		Mean Error at High Torque (DIFFH)	Mean Error at Low Torque (DIFFL)
Dio	Mean ± SD	1.16 ± 0.72	0.71 ± 0.61
	Number	11	11
Astra	Mean ± SD	1.23 ± 1.19	1.07 ± 1.37
	Number	6	6
Straumann	Mean ± SD	0.74 ± 0.81	0.56 ± 0.47
	Number	9	9
Biohorizon	Mean ± SD	3.83 ± 1.41	0.90 ± 0
	Number	4	1
Total	Mean ± SD	1.41 ± 1.33	0.74 ± 0.78
	Number	30	27

SD: standard deviation

In the tested wrenches only two wrenches were disinfected as opposed to autoclaved, one of which was made by Straumann and one by Biohorizon. In the Straumann wrench, a 2.2% torque error was observed at 35 N·cm and a 6% error at 15 N·cm and in the Biohorizon wrench a 14.3% error at 30 N·cm torque was reported, but due to the existence of only two specimens a statistical comparison could not be performed.

Discussion

In our comparison of spring torque wrenches with friction ones, our results show that at high torques (25, 30, 35 N·cm), spring wrenches are more accurate. An explanation for this issue can be found in the fact that a friction wrench has various moveable parts and mechanical connections including a ball and a socket in the tool-head and spring region. It is possible that these parts can become corroded and tightened. If the socket region is worn, its final torque will be decreased, while if the spring part is corroded, the spring's flexibility decreases and the final torque is increased.

High heat during sterilization can cause the lubricant inside friction wrenches to dry up and therefore the tool's accuracy decreases with increased use. For this reason it is recommended that friction tools are sterilized in a released mode and lubricated in a cyclic manner. On the other hand, torque application in a spring wrench is done by using a flexible tension arm with the magnitude of torque depending on the arm's flexibility and the distance under tension; therefore, the possibility of damage and corrosion to the parts of the wrench is lower. The value of the mean error in friction wrenches is reported here as 2±1.5 N·cm. Vallee et al. (7) showed a 3.83 N·cm error at peak torque that conforms to our study results; however, at low torque (15 N·cm), although the accuracy of the spring wrenches was higher than friction ones, the differences were not statistically significant.

In general, spring tools are more accurate than friction ones, but at low torques, frictional tools may be used with more reliability. In addition, based on a study by McCracken et al. (9) that compared spring and friction torque wrenches, friction tools can be said to have lower accuracy and more variety at high torques.

In the McCracken study, the standard deviation of the torque produced by friction wrenches was reported as ±16 N·cm, while it was ±1.1 N·cm in spring wrenches, which is much higher than the present study in terms of the error value in friction wrenches. There were seven friction tools included in the McCracken study and 18 friction tools in our study. In addition, two wrenches in the McCracken study were reported to have more than 50 N·cm torque, which increased the variation in error.

Our results showed that wrenches used in the Biohorizon system had a significantly greater error at high torques than Astra, Dio and Straumann wrenches. In the latter three groups of wrenches, the accuracy of Straumann wrenches was higher than Dio wrenches followed by Astra wrenches, but the differences were not statistically significant. However, it seems that the type of implant system used can have an effect on torque accuracy.

The fact that the Biohorizon and Astra wrenches are friction tools, but the Straumann and Dio ones are spring wrenches, may be a reason for the differences in accuracy but further studies are needed to understand why Biohorizon tools have significantly greater torque errors.

A study by Vallee et al. (7) examined the difference in the magnitude of the torque error in various systems. They concluded that spring-type wrenches are significantly more accurate in achieving the target torque than friction-type. Unlike the study by Vallee, a study by Standlee et al. (11) showed that the error produced by Noble Biocare tools was greater than other manufacturers. The study also showed that the magnitude of error for Straumann tools was in the range of 10%, which is similar to our study and suggests that Straumann wrenches have a high level of accuracy. Another study by Santos et al. (8) also reached the conclusion that Straumann tools had the highest accuracy among the four systems tested as we did, and showed that Noble Biocare tools produce a higher level of torque than other tools, which was not examined in the present study.

In the Santos study (8) the variation in error was reported to be greater at higher torques such that at 20 N·cm and 32 N·cm, only 62.5% and 37.5% of the wrenches tested produced an error of 10% or less, respectively. In the present study, at low (15 N·cm) and high torques (25, 30, 35 N·cm), 94.5% and 85% of the wrenches tested produced an error of 10% or less, respectively. This decrease in the number of accurate tools at high torques is similar in both studies but the percentage of accurate wrenches is higher in our study. Perhaps the reason for the difference in results is the low number of tools tested in the Santos study, which only tested 16 wrenches. The results from a study by Goheen et al. (13) show that mechanical tools have a low variation in the tolerance range of the system. The results from the present study indicate that the most common mechanical systems used in the clinics under examination have a high degree of accuracy.

When the tools were grouped by duration of use, 21.1% of the wrenches used for more than three years showed an error of more than 10% while only 9.5% of the wrenches used for less than three years did, indicating that with long-term use the accuracy of the devices will require more monitoring. In this study it was impossible to investigate the variable of sterilization on the accuracy of torque wrenches but this is important and should performed in future studies, especially in regards to torque wrenches used in the Biohorizon system where corrosion of the parts and components of the wrench should be controlled in the long-term.

In addition, old, unused wrenches should be compared with used new ones. In the clinic, we recommend that clinicians and dentists request a confirmation sheet for the accuracy/calibration of torque-applying tools from their sales representatives.

Conclusion

Our conclusions from this study are as follows:

1. At high torques (25, 30, 35 N·cm) spring torque wrenches are significantly more accurate than friction ones; therefore, care must be taken in using old friction wrenches. It is recommended with friction wrenches that the device be released once with the thumb before use. Also, annual testing and calibration is recommended. At low torques (15 N·cm), friction wrenches may be used with more reliability, though spring tools are more accurate.
2. The age and operational time of wrenches does not necessarily decrease their accuracy significantly; however, testing and calibrating tools older than three years is recommended.
3. The model of wrench used has an effect on accuracy; in particular, additional caution is necessary

when using Biohorizon torque wrenches, as the magnitude of the possible error magnitude in this system is significantly higher than in other systems.

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Corresponding Author:
Hamidreza Rajatihaghi
Department of Prosthodontics
Faculty of Dentistry
Vakilabad Blvd, Mashhad, Iran
Tel: +98-9155108528
Fax: +98-511-8829500
E-mail: hamidrus@yahoo.com