Variability of Mechanical Torque-Limiting Devices in Clinical Service at a US Dental School

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Keywords
Implant; torque wrench; mechanical torque-limiting device; preload.

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Financial support provided by the Department of Prosthodontics, UAB School of Dentistry.

Accepted December 5, 2008

doi: 10.1111/j.1532-849X.2009.00524.x

Abstract

Purpose: The purpose of this study was to measure the variability of torque produced by a population of mechanical torque-limiting devices in clinical service in a US dental school. The torque-limiting devices were divided into two categories according to their mode of action: toggle-type and beam wrenches. Proper action of these devices is essential for calibrated delivery of preload to implant prosthetic screws.
Materials and Methods: Seventeen torque-limiting devices (35 Ncm) were obtained from graduate prosthodontic, predoctoral, and faculty practice clinics. Nine of these were toggle-type devices, and eight were beam-type wrenches. Torque from each wrench was measured using an MGT electronic torque meter. Wrenches were tested in two modes, slow (over 4 seconds) and fast (over 1 second).
Results: Toggle-type torque wrenches produced a mean (± SD) torque of 38.1 ± 16.0 Ncm; beam-type wrenches produced 32.8 ± 1.1 Ncm. These results were not significantly different. When tested in fast mode (1 second), toggle-type wrenches produced 28.0 ± 9.6 Ncm; in the slow mode (4 seconds) they produced significantly more force, 36.6 ± 14.0 Ncm ($p < 0.001$). Beam-type wrenches produced 33.2 ± 1.1 Ncm and 32.8 ± 1.1 Ncm in fast and slow modes, respectively.
Conclusions: Both types of wrenches tested were capable of producing accurate torque values; however, variability was higher in the toggle-type group. Some toggle-type torque wrenches in clinical service delivered unacceptably high torque values. It is recommended that clinicians calibrate toggle-type wrenches frequently. Torque wrenches should be activated slowly, over 4 seconds, when using a correctly calibrated toggle-type wrench.

Dental prostheses are connected to implants and implant abutments with screws of different designs and materials. It has been noted that it is best to use the manufacturer's recommended screw design and alloy type for each implant and abutment.[1-3] An integral part of this process is tightening screws to an appropriate torque value. Evidence suggests that undertorquing an implant screw can lead to loosening, fracture, and failure of the screw,[4] and ultimately, the prosthesis. Overtorquing can lead to screw deformation, thread stripping, screw loosening, and fracture.[5]

Hand-held screwdrivers have been shown to produce inconsistent torque values on implant screws and abutments.[6] One study reported values of 8.2 to 36.2 Ncm when experienced operators used hand-held drivers in an effort to produce 32 Ncm of torque.[7] Dellinges and Tebrock measured torque applied to a hex wrench by dental students; the mean torque produced was 11.5 Ncm and was dependent on the experience level of the operator. They concluded that only some screws can be successfully tightened by hand.[8]

For these reasons, it has become standard practice to tighten implant screws with mechanical torque-limiting devices to place the recommended amount of torque on screws. This occurs both when placing abutments onto implants, and also when inserting screw-retained prostheses. At least two types of mechanical torque-limiting devices are in common clinical use, and a variety of terminology is used to describe them. The first type, called a click torque wrench in other industries, uses a ball detent system to disengage the lever arm at the desired torque and limit the torque applied. The ball is compressed into a spherical receptor (detent) and held in place by a spring. When the desired torque is applied, the ball rolls out of the detent, and the head of the wrench flips to the side, or toggles. This article will refer to this "friction" style or click torque wrench[9] as a toggle-type wrench (Fig 1). Another type of mechanical torch device examined in this article is the beam type, or "spring" torque-limiting device (Fig 1). When pressure is applied to the beam, it deflects, and this spring action applies a torque to the screw. The amount of torque can be varied by how far the beam

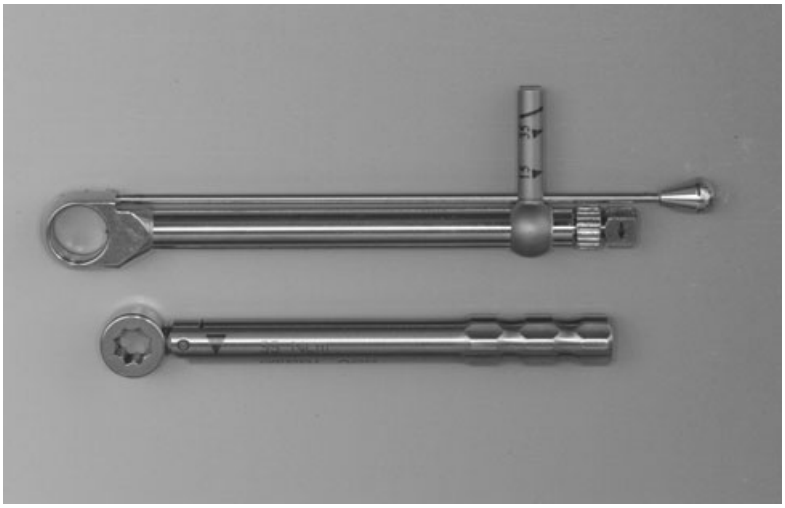

Figure 1 Mechanical torque-limiting devices (torque wrenches) used in implant dentistry. The beam-type torque wrench (above) uses a simple spring (stiffness of the tension arm) to achieve torque values. Toggle-type torque wrenches (below) use a ball detent mechanism with an internal coiled spring to mechanically limit applied torque.

is deflected; most dental devices have a gauge with markings to indicate the applied torque. One advantage of this device is that multiple torques can be applied using the same device, while the toggle-type devices are limited to one value. The deflected beam device will be referred to in this article as a beam torque wrench.

A few studies have examined mechanical torque device reliability. Standlee et al evaluated three mechanical devices to determine accuracy of torque applied.[10] They concluded that both toggle torque wrenches and beam torque wrenches were within 10% of target values for torque. It should be noted that the wrenches used in this study were new and had not been in clinical service. The authors also concluded that wrenches produced a more reliable torque when activated slowly. A more recent manuscript concluded that the beam torque wrench produces a torque closer to nominal values than the toggle-type torque wrenches. The deviation for the beam devices was 0.82 Ncm, while the variation for the toggle-type devices was 3.83 Ncm. All the devices measured in this study were also new. The literature suggests, however, that clinical use and sterilization may affect torque values,[11] and torque values may change after multiple uses.[12]

In a study of devices found in clinical use, Gutierrez et al reported maximum deviations of up to 58% of stated values, and also one 10 Ncm toggle-type wrench that applied 455% of the stated torque value.[13] Another study of beam torque wrenches found a very slight decrease in applied torque after wrenches had been used and sterilized up to 1000 times. Torque values decreased 1.5 Ncm compared to newer wrenches, and this difference was significant.[12] In other disciplines, such as orthopedics, variability of torque devices is also noted, with measured torque falling within 10% of the target value in 69.2% of torque applications.[14,15]

Instead of using a mechanical device, clinicians may attempt to apply a specific torque using finger pressure. This has been shown to be highly unpredictable.[16] Even if a small percentage of clinicians are able to obtain the force necessary to apply the torque, the amount of torque applied is not consistent.[6] Other studies show that finger pressure is not sufficient to apply recommended preload to the clamping system.[17] One study reported that the amount of torque applied with finger pressure on an implant wrench averaged 11.55 Ncm, far below many of the required 20 and 30 Ncm application requirements.[8] Other torque devices, such as electronic torque controllers, have demonstrated unacceptable variability, up to 165% of target values.[17,18]

Taken together, the literature describes considerable variation among torque wrenches. The purpose of this study was to measure the consistency of torque produced by a population of mechanical torque-limiting devices found in use at a US dental school.

Materials and methods

Mechanical torque-limiting devices found in service at the University of Alabama at Birmingham School of Dentistry were collected for this study. Only torque wrenches designed to deliver 35 Ncm torques were examined. Wrenches were obtained from graduate prosthodontic, predoctoral, and faculty practice clinics. In total, 17 devices were examined. Nine of these were toggle-type devices, and eight were beam-type wrenches.

An MGT electronic torque meter with a 3-jaw Jacob's chuck was obtained to measure the torque applied by each wrench (Mark-10, Copiague, NY). This device was recently calibrated by the manufacturer and has a standard accuracy of 0.5 Ncm. The torque meter was fixed in a vise for stability. All torque wrenches were purchased from the same vendor (Nobel Biocare, Goteborg, Sweden). The wrenches ranged from an estimated 18 months to 7 years of clinical use, representing up to 700 clinical use and sterilization cycles.

A single operator tested each torque wrench five times; these readings were recorded, and the average torque was reported in Ncm for each wrench. Each wrench was tested by applying the torque slowly, over 4 seconds.[10] The mean torque values of toggle-type and beam-type torque wrenches were compared using ANOVA (SAS v9.0, SAS Institute, Cary, NC).

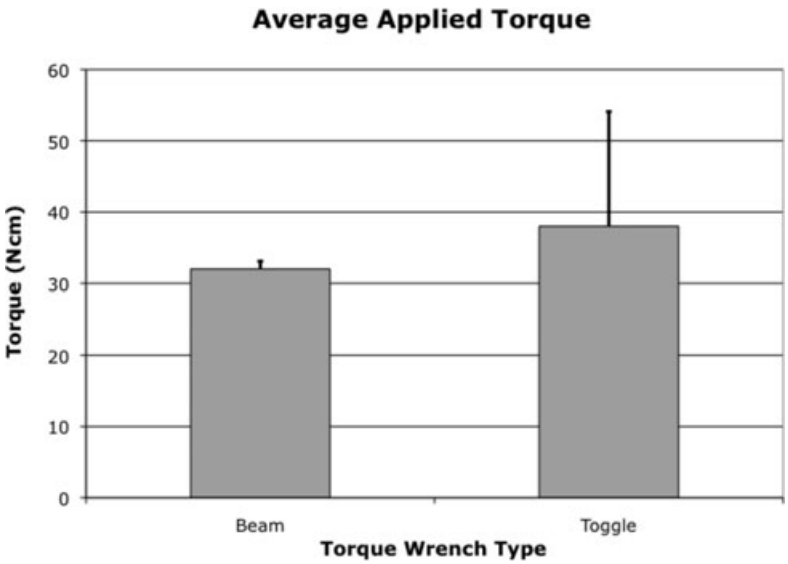

Figure 2 Average applied torque by wrench type (± SD). No difference in the mean applied torque was noted between beam- and toggle-type torque wrenches; however, the toggle-type torque wrenches demonstrated much greater standard deviation.

Each wrench was also tested in a fast mode, with torque applied over 1 second. Each wrench was tested five times in each mode. Data were stratified by wrench type (toggle or beam), and the differences in mean torque for each wrench by speed of torque application were tested using a paired *t*-test (SAS v9.0). All statistics were performed with alpha = 0.05.

Results

Mean torque (± SD) produced by toggle-type torque wrenches was 38.1 (± 16.0) Ncm, and torque produced by beam-type wrenches was 32.8 (± 1.1) Ncm. These values were not significantly different. It is noted, however, that the standard deviation among the toggle-type wrenches was over 14 times greater than the standard deviation for beam-type wrenches (Fig 2). The range of torque values produced by the toggle-type torque wrench was 18.8 to 74.7 Ncm. The range of torque values produced by beam-type torque wrenches was 31.7 to 35.2 Ncm.

Toggle-type wrenches produced significantly different torque values when tested in the fast (1-second) and slow (4-second) modes ($p < 0.001$). When tested in the fast mode, toggle-type wrenches produced a mean torque of 28.0 Ncm (± 9.6), while toggle-type wrenches tested in the slow mode produced 36.6 Ncm (± 14.0). Beam-type wrenches produced mean torque of 33.2 Ncm (± 1.1) in the fast mode and 32.8 Ncm (± 1.1) in the slow mode; these values were not significantly different (Fig 3).

Discussion

This study was performed to determine if a specific set of torque wrenches in use in an academic institution applied a clinically suitable torque, which for the purposes of this study

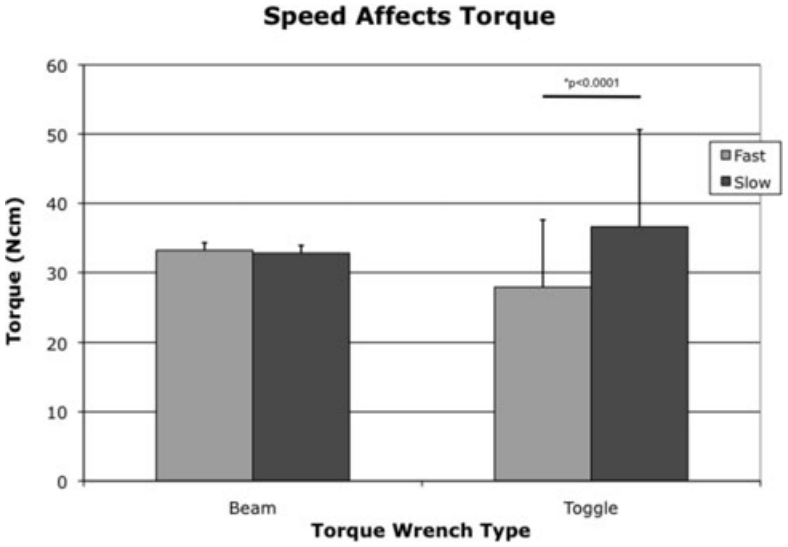

Figure 3 Torque associated with speed of action by wrench type (± SD). Toggle-type implants activated slowly (over 4 seconds) had significantly higher torque values than when activated quickly (over 1 second; $p < 0.001$). Beam-type torque wrenches were not affected by speed.

was defined as torque values within 10% of the target torque of 35 Ncm.[10] The results of this study will not apply to every clinical situation, as too many confounding variables associated with sterilization, maintenance, and use exist; however, several interesting trends were noted.

Toggle-type torque wrenches were sensitive to speed. When torqued quickly, over 1 second, torque values were significantly lower than when torqued over 4 seconds. If the toggle-type wrench was functioning properly, the values for the slow mode were more consistent with nominal values of 35 Ncm. Excluding two wrenches that produced outlying high torque values and were judged clinically to have a stiff action, the mean torque of the toggle-type wrenches in the slow mode was closer to the 35 Ncm nominal torque value, while the fast mode average was low. In other words, with a well-maintained and calibrated torque wrench, activating the wrench slowly produced the most accurate and consistent results. This finding supports similar results reported by Standlee et al.[10] Beam-type torque wrenches were not affected by speed of use.

The mode of action for toggle- and beam-type torque wrenches is uniquely different. The toggle-type wrench contains several moving parts and mechanical moving connections, including a ball that fits into a recessed socket in the head and a spring. It is noted in the literature that these parts can become corroded and stiff over time, leading to improper torque delivery.[13] In contrast, the beam-type torque wrench applies a torque by using a single flexible metal spring, or tension arm. The torque applied depends on the flexibility of this arm and the distance it is pulled, rather than a ball-and-socket configuration. Both types of devices can be found in other industries used to apply torque.

In this study, the mean applied torque of toggle- and beam-type torque wrenches was not significantly different; however, it should be noted that the range of values produced by the toggle-type torque wrenches was considerably greater than that of the beam-type torque wrenches (55.9 Ncm vs. 3.5 Ncm). This is also reflected in the standard deviation of each group (16.1 Ncm vs. 1.1 Ncm). Overall, the beam-type torque wrench delivered more consistent torque. This general effect was caused in large part by two toggle-type torque wrenches that were "frozen" to some degree and produced very high values (in excess of 50 Ncm). Both of these wrenches were identified by the operator as "heavy." In effect, these two wrenches could only be pushed over with difficulty using thumb pressure. Both were removed from clinical service for calibration.

These data suggest that clinical use and autoclaving the torque wrench in an institutional environment may be associated with an increase in torque well above nominal values. This may be because the heating process congeals the lubricant inside the toggle-type torque wrench, jamming the action and increasing the applied torque. While in a private-practice environment more care may be exerted over strict protocols for sterilizing torque wrenches, this is more difficult in an institution with multiple clinicians and staff members. Generally, manufacturers recommend sterilizing the device in the broken or toggled position, with the use of an approved lubricant. Beam-type torque wrenches did not appear to be dramatically affected by steam or cold sterilization. Some authors show a slight decrease in applied torque with beam-type devices due to sterilization,[12] but this decrease was not considered clinically relevant by the definitions presented in this trial, a change exceeding 10% of nominal values.

Unfortunately, the exact age and the actual number of sterilization cycles of the torque wrenches examined in this study were not known. These are deficiencies in the study; however, the fact was that the torque wrenches were all in clinical service at the time of the investigation, and they therefore give a cross-sectional view of what may be present in a similar clinic environment.

Overall, either type of torque wrench can be accurate. The toggle-type torque wrench appears to be more sensitive to use in sterilization procedures than the beam type. When using the toggle-type torque wrenches, it is recommended that the clinician flip the head with thumb pressure before applying a load to an implant screw to make sure the wrench is working properly. In addition, frequent (annual) calibration of these torque wrenches is recommended. Some implant companies calibrate toggle-type torque wrenches in-house, while others ask the clinician to contact the manufacturer of the torque wrench directly. Such third-party vendors are able to calibrate a variety of toggle-type wrenches, regardless of the implant company associated with the wrench; a typical fee for calibration is around $35 plus parts (ITL Dental, Irvine, CA). The beam-type torque wrenches, with fewer moving parts to wear or jam, seem to produce more consistent torque values, and are therefore less likely to require maintenance.

Conclusions

In this population of implant mechanical torque-limiting devices, the following conclusions are made:

(1) Toggle-type torque wrenches produce significantly more torque when activated slowly, over 4 seconds, compared to 1 second. The torque produced in the slow mode was more consistent with desired values.
(2) While toggle-type and beam-type torque wrenches produce average torque values close to their nominal value of 35 Ncm, the range of values and variability was greater among the toggle-type wrenches.
(3) Mechanical torque-limiting devices should be checked and calibrated according to manufacturer's instructions, typically on an annual basis.

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