

A survey for the use of torque-limiting devices among dental clinicians in Europe

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Abstract

Purpose: To assess how well torque-limiting devices (TLDs) are known and used by European dentists, and their adherence to screw tightening protocols and screw loosening occurrence through a survey, including the correlation between the dental specialty-of-interest and the recognition, the tightening protocol used, and between the calibration and the occurrence of screw loosening.

Materials and methods: A 10-question survey was distributed to dentists to collect data on their specialty-of-interest, TLD usage, knowledge on TLDs, calibration, the term “preload,” tightening speed, tightening protocols used, and occurrence of screw loosening. Pearson test was used for correlation analysis between the specialty-of-interest and the recognition-based questions, the tightening protocol used, and between the calibration and the frequency of screw loosening.

Results: Of 422 respondents, 24% calibrated their TLDs, 27% knew the term “preload,” 76% selected the correct location to read on TLDs, and 6% was aware of the effect of tightening speed. The correlation between the specialty-of-interest and the recognition-based questions was nonsignificant ($p < .05$) but was significant for used tightening protocol ($p < .001$). The correlation between the calibration and the occurrence of screw loosening was nonsignificant ($p = 0.16$). Tightening protocols' effect on screw loosening was similar, which was mostly observed less than once a year ($p < .001$).

Conclusions: A lack in dentists' knowledge was found on calibration, the term preload, and the effect of tightening speed, which were not impacted by the dentists' specialty-of-interest, which affected the preferred tightening protocol. The tightening protocol and calibration did not impact the occurrence of screw loosening, which was mostly observed less than once a year.

KEYWORDS

calibration, dental abutments, dental prosthesis, implant-supported, torque

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1 | INTRODUCTION

In recent years, implantology has revolutionized the field of prosthodontics, offering a range of significant advantages. The remarkable progress in implantology has led to improved esthetics, enhanced functionality, increased durability, and patient satisfaction (Huang & Wang, 2019; Mcglumphy et al., 1998). This rapid development in implantology has resulted in multiple advanced prosthodontic treatments available. These technological advancements have opened new possibilities for patients and clinicians seeking effective, long-lasting treatment alternatives. However, implant-related biological or mechanical complications in implant-supported dental prostheses have also been encountered; screw loosening is one of the most common complications in implant-supported dental prostheses (Jacobs et al., 2022; Wadhvani et al., 2021). Various contributing factors may lead to screw loosening, which include the design of the material, abutment connection type, restoration type, and clinician- or patient-related factors (Binon, 2000; Huang & Wang, 2019; Kim et al., 2012).

Screw loosening has a concurrency of approximately 5% during the first year of prosthetic treatment and 6–12% after 5 years (Huang & Wang, 2019; Wadhvani et al., 2021). The use of specialized tools like torque-limiting devices (TLDs) has been recommended with (Albayrak et al., 2017; Goldstein et al., 2020; O'Brien et al., 2021; Standlee et al., 2002) and standardized tightening protocols to minimize screw loosening. Today, many dentists use TLDs in their clinical practices every day to place implants and tighten abutments or prosthetic screws (Goheen et al., 1994; Goldstein et al., 2020; L'Homme-Langlois et al., 2015; McCracken et al., 2010; O'Brien et al., 2021; Wadhvani et al., 2021). There are industry standard guidelines for maintenance and correct usage presented by the International Organization of Standardization (ISO) (ISO-6789 1,2:2017) about TLDs, which are also referred to as torque wrenches (ISO 6789-1, 2017).

It would be beneficial to identify factors, which cause screw-related failures to minimize/prevent them from happening (Vallee et al., 2008; Wadhvani et al., 2020; Yilmaz et al., 2015) according to a previous study (Wadhvani et al., 2021), and abutment material, screw morphology, patient-related factors, and screw tightening protocols were emphasized. However, to the authors' knowledge, there is limited information in the literature about the clinical aspect of how dentists use TLDs and whether they know/follow the protocols for optimized screw tightening. The only available study on this subject examined the knowledge and experience levels of dentists in the United States (US) regarding the use of TLDs and screw tightening procedures (Wadhvani et al., 2021). The study revealed significant variation in the answers provided by the dentists, indicating a lack of consistency in their understanding. This survey was exclusively shared with the clinicians within the United States, and no published papers have yet explored the knowledge of European dentists regarding the use of TLDs and screw tightening. Therefore, conducting a survey in Europe to assess the behavior and knowledge of dentists regarding TLDs could contribute to a better understanding of dentists' knowledge and provide valuable insights for TLD manufacturers and dental school educators to validate or

potentially reconsider training methods for screw tightening protocols. By preventing or minimizing errors associated with screw or abutment-related complications, these efforts could reduce inconveniences in terms of time and cost. In addition, findings could help in determining whether European dentists' responses align with those of dentists overseas. Exploring regional differences and dentists' adherence to standard protocols and then enhancing knowledge and adherence to recommended practices may reveal clinical implications that can benefit dentists and manufacturers, further improving patient outcomes.

The primary objective of this study was to assess the knowledge on TLDs and screw tightening protocols among dental clinicians in Europe and compare it to industry standard guidelines (ISO). In particular, any correlation between the dentists' dental specialty-of-interest and their knowledge on TLD calibration, reading of the torque value on beam-type TLDs, the term "preload," their awareness of the effect of tightening speed on TLD's performance, and the tightening protocol used were assessed. The correlation between the implementation of calibration and the frequency of screw loosening was also aimed to be evaluated. The responses given to two separate, but similar, surveys conducted in the United States and Europe were evaluated to gain a comprehensive understanding of the subject matter, identifying similarities and differences. The null hypothesis was that the majority of the dentists would follow the ISO 6789-2 guidelines for TLD usage.

2 | MATERIALS AND METHODS

The study is exempt from ethics approval with the case number of Req-2021-01045, from Swissethics commission. A previously developed survey (Wadhvani et al., 2021) was used with the addition of one question in the present study. Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools (Harris et al., 2009, 2019). The survey was transferred into an electronic form and a link was generated, which could be distributed over email correspondence. The link was accessible from January 2022 until May 2023. The gathering of the data was done anonymously without any tracking or other form of personal information. The survey was available in two languages (English and German). For the database, several dental boards in different countries and cities in these countries were reached and the survey was distributed to dental schools and practicing private practitioners, who restore implants. The completion of the 10-question survey is roughly 5 min, and the participation was voluntary (Figure 1).

2.1 | Demographic data collection

Questions 1–5 were gathering demographic information including dental specialty-of-interest, the type of TLD owned, field and duration of use, and the frequency of experienced screw loosening over a year period.

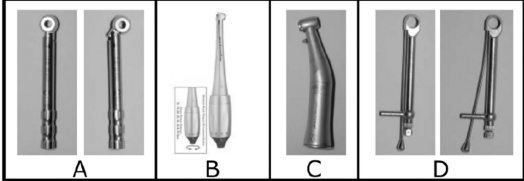
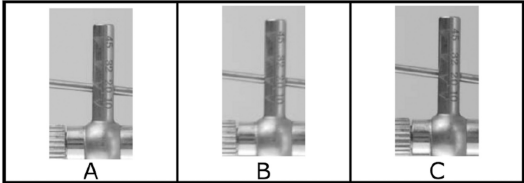
1) In which area are you mainly active?	<input type="radio"/> I am mainly involved in surgery <input type="radio"/> I mainly practice prosthodontics <input type="radio"/> I practice implant surgery and prosthodontics in roughly equal proportions
	
2) Which type(s) of torque wrench do you have (multiple selections possible)?	<input type="checkbox"/> A) Toggle Type <input type="checkbox"/> B) Variable manual <input type="checkbox"/> C) Electric <input type="checkbox"/> D) Beam/Bar-Type
3) How long have you had your torque wrench?	<input type="radio"/> Less than 1 year <input type="radio"/> 1-3 years <input type="radio"/> More than 3 years
4) When do you use it most often (multiple selections possible)?	<input type="checkbox"/> Surgical placement of the implant <input type="checkbox"/> Placement of the healing cap <input type="checkbox"/> Tightening of the abutment <input type="checkbox"/> Testing the implant integration
5) How often have you seen screw loosening in an implant restoration?	<input type="radio"/> Never <input type="radio"/> Very rarely (less than once a year) <input type="radio"/> Rarely (3-4 times a year) <input type="radio"/> More than 5 times a year
6) Have you ever calibrated your torque wrench?	<input type="radio"/> Yes <input type="radio"/> No
	
7) For a "Beam Type" torque wrench, 20Ncm is most accurately represented by:	<input type="radio"/> A) Bottom edge of the bar at the 20 mark <input type="radio"/> B) Center of the bar at the 20 mark <input type="radio"/> C) Top edge of the bar at the 20 mark
8) What is "Preload" of a screw?	<input type="radio"/> Hand tighten the screw before using a torque wrench <input type="radio"/> Tightening the screw to a certain value, testing by lateral chewing <input type="radio"/> Tensioning the screw to generate the clamping force <input type="radio"/> Waiting time between each tightening of the screw, so that the screw can settle
9) Does the speed of tightening have an effect when using a "beam/bar type" or "toggle type" torque wrench?	<input type="radio"/> No <input type="radio"/> Yes for both <input type="radio"/> Only for "beam/bar type" torque wrench <input type="radio"/> Only for "toggle type" torque wrench <input type="radio"/> I do not know
10) How do you proceed when tightening the final restoration/abutment using a torque wrench?	<input type="radio"/> Tighten once to the required value <input type="radio"/> Tighten once to the required value, wait a few minutes, and tighten again <input type="radio"/> Tighten once to the required value, 1 week later patient revisits for re-tightening <input type="radio"/> Tighten more than once to the required torque without waiting <input type="radio"/> Tighten to the required value, loosen and tighten again to the required value

FIGURE 1 The 10-question survey.

2.2 | Recognition information

Questions 6–9 focused on the calibration of the TLD, reading of the torque value, understanding the term "preload," and the knowledge on the potential effect of tightening speed.

2.3 | Usage information

Question 10 addressed the tightening protocol followed when tightening a screw. The data collection was done all over Europe, and the questionnaire was distributed in English and German. All responses were reviewed by one researcher following the Declaration of Helsinki protocols.

2.4 | Data analysis

The evaluation and organization of the data was done in Microsoft Excel 2022. The numbers of answers in each question were calculated as a percentage and visualized with pie diagrams according to the numbers of respondents in the results section.

The total number of responses was expected to be potentially different than the number of respondents, because there are some questions with more than one choice and not every respondent answered all questions. The percentages of responses for question 5, selected by those who chose option C for question 4 (defining respondents using TLDs for abutment tightening) and correct answers for questions 7–10, were evaluated to evaluate the effect of used protocols on abutment screw loosening, by using a statistics software; R Foundation for Statistical Computing). Additionally, data were subjected to further analysis through the Pearson chi-square test to explore potential associations between Question 1 and other survey questions. The same procedure also applied to questions 5 and 6 to evaluate whether there was an association between the responses to these two questions. Pearson chi-square test is employed for analyzing categorical data, assessing the correlation between variables. Specifically, it examines the significance of differences between categorical variables by comparing observed and expected frequencies. Given the categorical nature of the data in this study, this test was chosen for statistical analysis.

3 | RESULTS

A European cohort of clinicians answered the survey, which provided the data. The dental boards, including prosthodontics, oral surgery, periodontology, and implant dentistry in Europe, were reached out and following country boards responded to the survey sharing request: Denmark, Switzerland, Germany, Italy, France, Serbia, Spain,

and Türkiye. Over 1 year, the survey was filled out by 422 clinicians. Every question was fully answered, except for two questions: one related to TLD type (question 2) and the other to the term “preload” (question 8). Both of those questions were only answered by 408 out of 422.

3.1 | Demographic information

The analysis of clinicians' specialty-of-interest revealed that 42% were active in prosthodontic work, and 41% equally divided their practice between prosthodontics and surgery (Figure 2). The beam-type TLD was the most used (57%), followed by the toggle type (Figure 3). Most of the clinicians (66%) used their TLDs for more than 3 years (Figure 4). The TLDs were used for more than one procedure, 422 clinicians providing 654 answers. Most of the clinicians (55%) used TLDs for the abutment tightening, followed by surgical placement (28%) (Figure 5). Only 10% of the clinicians reported that they had never experienced screw loosening for an implant restoration (Figure 6).

3.2 | Recognition information

Almost one quarter (24%) of the clinicians indicated that they calibrated their TLDs (Figure 7). There was no significant association between the implementation of calibration and the frequency of screw loosening ($p = .16$). Among respondents using TLDs for abutment tightening, those who calibrated their TLDs experienced a frequency of less than one screw loosening per year at a rate of 61.8%. The respondents using TLDs for abutment tightening, who

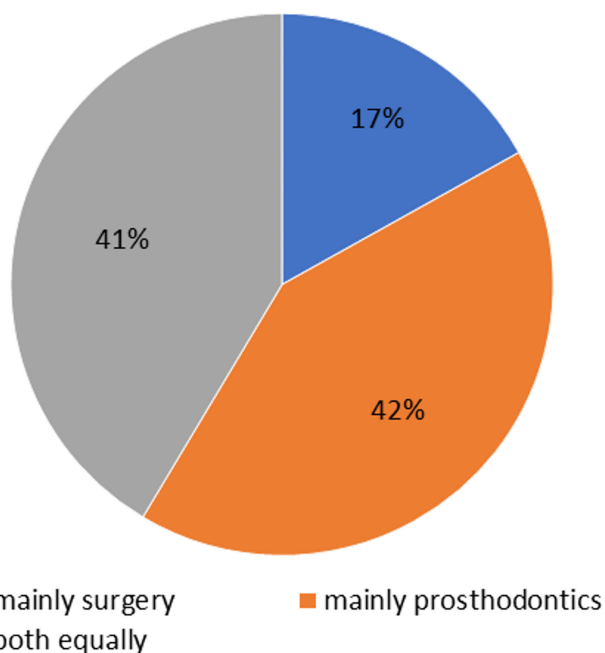


FIGURE 2 Percentage of the clinicians work field ($n = 420$).

did not calibrate, also reported a similar frequency, 56% experiencing less than one screw loosening per year (Table 1). Additionally, the Pearson chi-square test assessed the relationship between the specialty-of-interest and the knowledge-based questions. In this context, no significant association was found between question 1 and questions 6, 7, 8, and 9, indicating no significant correlation between specialty-of-interest and the understanding of calibration, reading of the torque value on beam-type TLD knowledge on the term “preload,” and awareness of the effect of tightening speed ($p = .50$, $p = .92$, $p = .62$, $p = .77$, respectively).

Regarding the correct position of the marker arm, when using a beam type TLD, 76% of the respondents selected the correct option “in the center of bar” (Figure 8). When asked about the preload, 27% of 408 respondents showed comprehension of the term. Among them, 32% chose hand tightening, 36% chose “time for settling,” and only 5% believed it meant “tighten then lateral test” (Figure 9). Regarding the speed of tightening, almost half of the clinicians (46%) did not know whether the speed of tightening had an effect when using a beam- or toggle-type TLD for tightening. The correct answer was only provided by 6% knowing that the speed had an effect when using the toggle-type TLD (Figure 10).

3.3 | Usage information

According to 418 respondents, the tightening protocol was most often (43%) “tighten, then wait a few minutes and retighten.” Only 21% tightened the abutment screw once with the TLD. 22% tightened the screw again after 1 week (Figure 11). The results of the Pearson chi-square test indicated statistically significant association between specialty-of-interest and screw tightening protocols for questions 1 and 10, revealing that prosthodontists mostly wait a few minutes between tightening points, whereas surgeons prefer waiting 1 week between two tightening points ($p < .001$; Table 2). Among respondents, who used TLDs for abutment tightening, whether they tightened it twice with a few minutes of an interval or waited for 1 week, screw loosening was observed less than one screw loosening per year at a rate of 57.9%. Similarly, those who tightened the abutment only once, tightened it more than once without waiting, or initially tightened, then loosened and tightened again, also reported screw loosening as less than one per year at a rate of 54.3% (Tables 3 and 4). Additionally, the effect of tightening protocols on screw loosening was consistently observed as less than once a year ($p < .001$). Furthermore, the respondents who used TLDs for abutment tightening and were aware that the speed of tightening had an effect when using a toggle-type TLD experienced less than one screw loosening per year (70%).

4 | DISCUSSION

The results of this survey revealed that the beam-type TLD was the most used TLD among the respondents (57%). Interestingly, this percentage closely aligns with the findings of a similar survey conducted

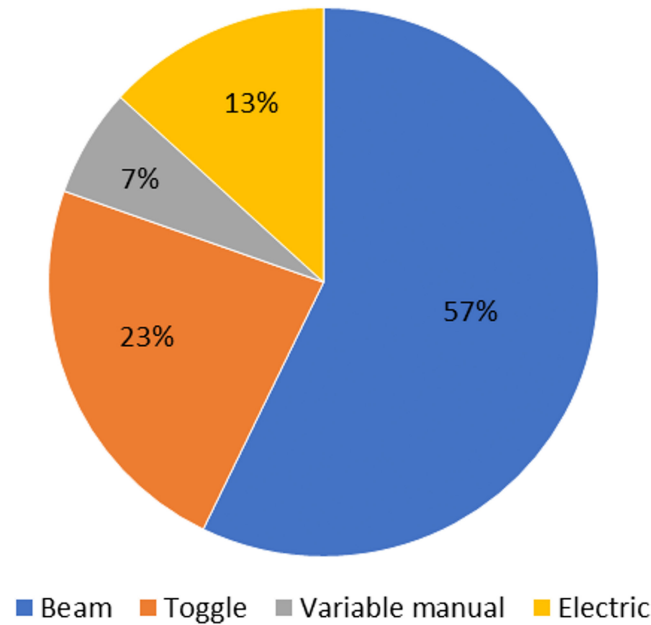


FIGURE 3 Percentage of the different torque-limiting device (TLD) types possessed by clinicians; some had more than one type. *n* = 673; respondents, *n* = 422.

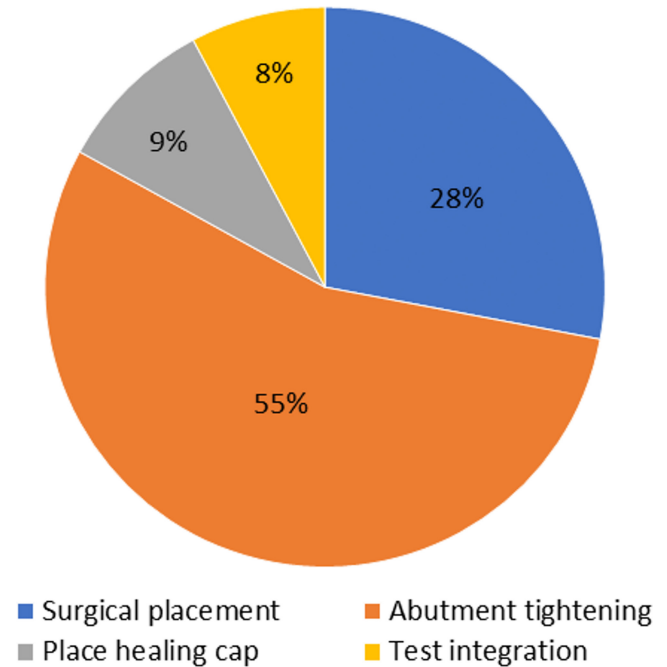


FIGURE 5 Percentage of the use of torque-limiting devices (TLDs) for different procedures by the clinicians (usage, *n* = 654; respondents, *n* = 422).

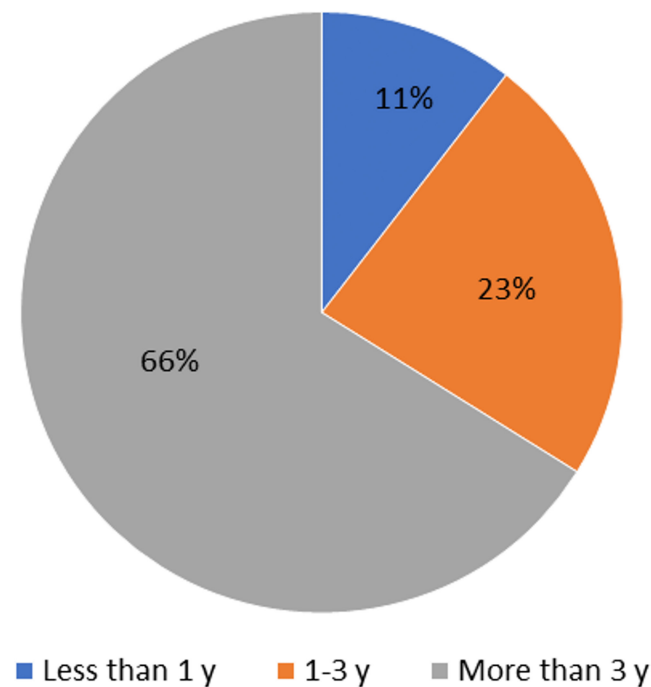


FIGURE 4 Percentage of the age of torque-limiting devices (TLDs) (*n* = 419).

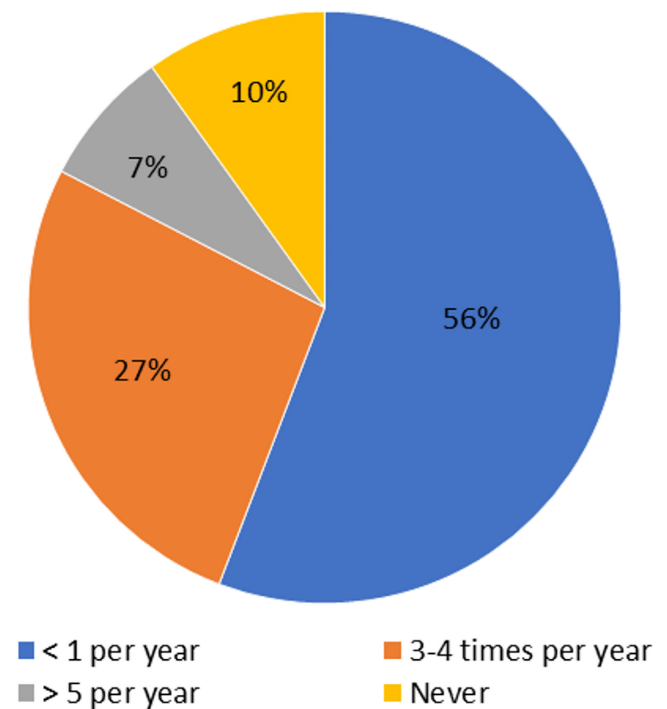


FIGURE 6 Frequency of screw loosening by clinicians (*n* = 414).

in the United States, where 60% of participants reported the use of beam-type TLDs (Wadhvani et al., 2021). ISO 6789-1:2017 (ISO 6789-1, 2017) classifies the hand torque tools into two types, Type I and Type II. The beam-type TLD is Type I, while the toggle-type, also known as the spring-type (Stroosnijder et al., 2016), is classified as Type II. The beam-type TLD is characterized by its beam-shaped

elastic metal component, which enables deflection when the force is applied. It does not have any moving parts (Wadhvani et al., 2020). Conversely, toggle-type devices are friction-based units that contain moving parts. Due to these moving components, they can be more susceptible to aging and deformation (Gutierrez et al., 1997).

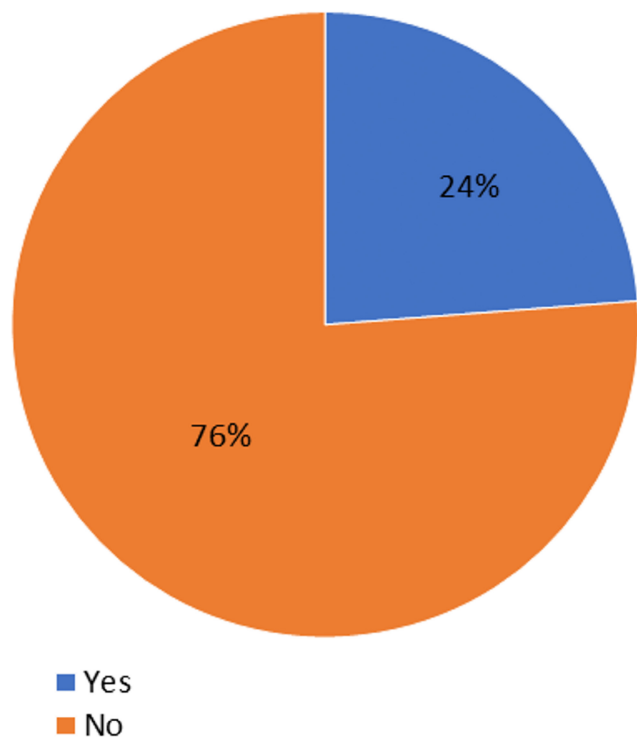


FIGURE 7 Percentage of clinicians who had calibrated their torque-limiting devices (TLDs) ($n=416$).

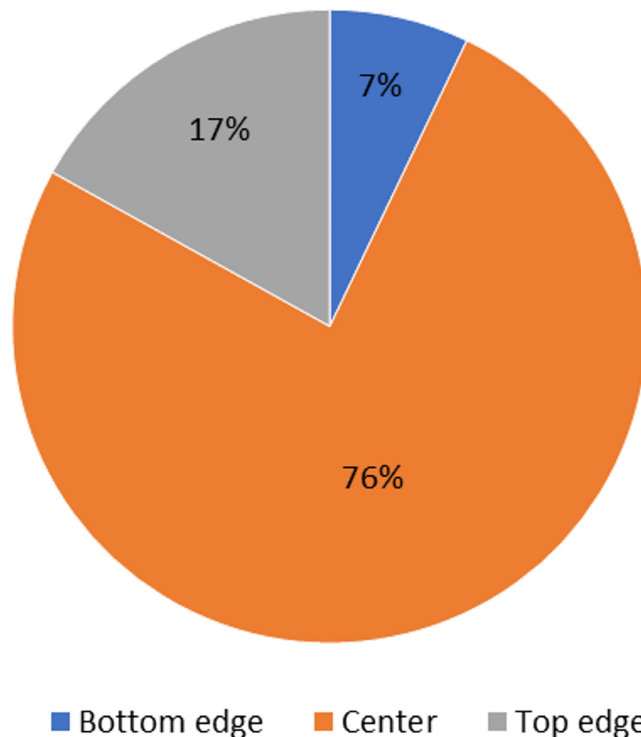


FIGURE 8 Percentage of clinicians who did read the torque value in the wright position from a beam-type torque-limiting device (TLD) ($n=408$).

Q6	Q5				<i>p</i>
	Never	Less than once a year	3–4 times a year	More than 5 times a year	
Yes	9 (11.8%)	47 (61.8%)	14 (18.4%)	6 (7.9%)	.161
No	20 (7.3%)	154 (56%)	83 (30.2%)	18 (6.5%)	

TABLE 1 Association between the implementation of calibration (Q6-Yes/No) and occurrence of screw loosening (Q5).

Properly tightening the abutment screw to the recommended torque is crucial in clinical practice (Goheen et al., 1994; Kanawati et al., 2009; Mcglumphy et al., 1998; Standlee et al., 2002). Finger tightening is not recommended for achieving the necessary torque, as the force applied during this method can vary widely depending on the clinician and range from 11 to 38 Ncm (Kanawati et al., 2009). Goheen et al. (1994) reported that TLDs can be used for adequate tightening. The elastic deformation characteristics of the screw itself, following the recommended torque while tightening the abutment screw, are crucial to prevent screw deformation. Therefore, it is important to recognize that higher than necessary torque is not always the optimal choice for screw-retained implant-supported dental prostheses (Huang & Wang, 2019).

Screw loosening is recognized as one of the most common mechanical complications in implant-supported dental prostheses (Kim et al., 2012; Standlee et al., 2002). More than half of the respondents (56%) in this study indicated experiencing less than one screw loosening in a year, while 27% reported encountering screw loosening at least 3–4 times per year. Latter percentage closely aligns with

that in the previous study (Wadhvani et al., 2021) in which 33% of participants reported experiencing 3–4 times of screw loosening in clinical practice. It is important to note that screw loosening is influenced by a multitude of factors (Huang & Wang, 2019; Mcglumphy et al., 1998). Therefore, it is important to take caution when interpreting the survey findings conducted in both studies.

The results of this survey revealed that only 24% of clinicians followed the (ISO) 6789-2 protocols and calibrated the TLDs after use. Consequently, the null hypothesis was rejected, as the majority of dentists were not adhering to the ISO 6789-2 guidelines for TLD usage. The ISO protocols recommend the calibration of TLDs every 12 months or 5000 cycles, and following the sterilization process, as these factors can have a negative effect on the performance of the devices. The study findings indicated that although most of the respondents (66%) have been using their TLDs for >3 years, a high percentage (76%) of the participants reported that they would not calibrate their TLDs, only 24% of them calibrating. These results are different when compared with the US-based survey, where only 6% of the respondents calibrated their TLDs. The present

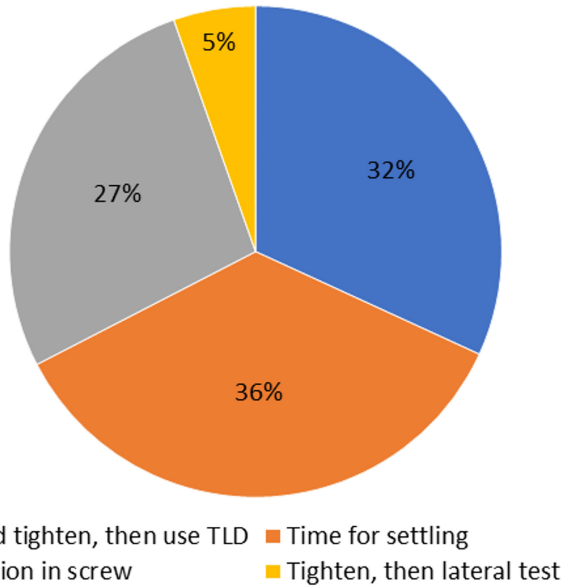


FIGURE 9 Percentage of clinicians who knew the definition of preload (n=408).

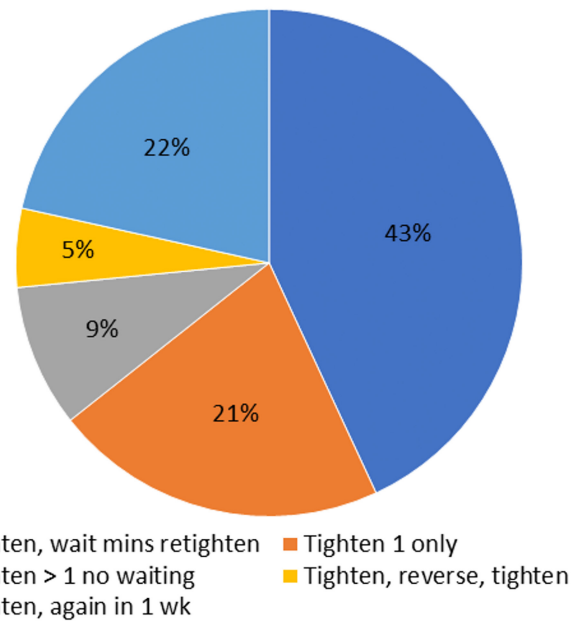


FIGURE 11 Percentage of clinicians' knowledge about screw tightening protocols (n=418).

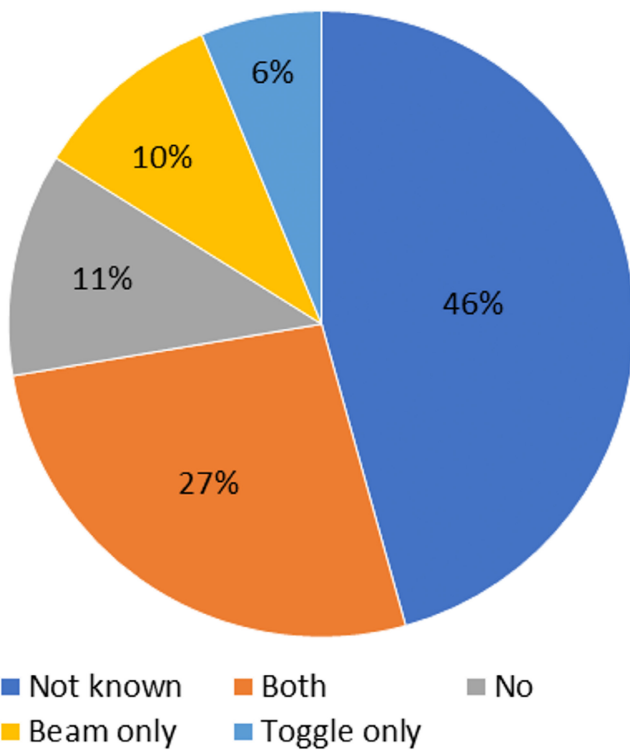


FIGURE 10 Percentage of clinicians to the affect of speed when tightening with a torque-limiting device (TLD) (n=416).

study results revealed similar screw loosening frequency for dentists who calibrated their TLDs and for those who did not calibrate. Nevertheless, it can be concluded that whether the dentists adhere to the calibration protocol or not, there is an educational gap on this subject matter.

Preload is the initial load on a screw created by torque application, and it is influenced by several factors (Mcglumphy et al., 1998).

Higher torque delivery results in greater preload, which can enable the resistance of the screw to loosen; therefore, knowledge of the dentist on the mechanism of torque application, particularly on the relationship between the preload and screw loosening, can be beneficial to minimize the occurrence of screw loosening. In addition, the maximum preload is typically observed at the point of screw fracture. Accordingly, to prevent screw fracture during TLD usage, a safety margin is established. Ensuring the application of forces within the safety limits during screw tightening is of utmost importance (Mcglumphy et al., 1998). Based on the results of the European and US-based surveys, it can be concluded that a significant percentage of dentists were unaware of the exact meaning of preload. This finding was potentially supported by 14 out of 422 respondents not answering the preload question. Specifically, in the present survey, 27% of the respondents indicated a lack of knowledge, while in the US-based study, this value was 14%. These findings highlight a knowledge gap among dentists regarding the meaning of preload.

Most of the respondents, who were using beam-type TLDs (76% of 57%), gave the correct answer that they did read the torque value on the center on the beam-type TLD. This result is also consistent with the previous study where 66% respondents reported the correct use of beam-type TLD (Wadhvani et al., 2021).

The present study also revealed a lack of knowledge among most clinicians regarding the ISO-6789 guidelines on calibration, particularly with regard to toggle-type TLDs. Most of the respondents incorrectly used toggle-type TLDs, despite these tools being friction-based and susceptible to tightening speed when increasing the torque. Moreover, only 6% of the respondents were aware of the impact of the speed on the torque applied with toggle-type TLDs. This finding aligns with the results of the previous survey, where a similar result of 5% awareness was observed. Based on

TABLE 2 Specialty-of-interest (Q1) and preferred screw tightening protocol (Q10) association.

Q10	Q1			Total
	I am mainly involved in surgery	I mainly practice prosthodontics	I practice implant surgery and prosthodontics in roughly equal proportions	
Tighten once to the required value	21 (30.4%)	26 (14.9%)	42 (24.3%)	89 (21.3%)
Tighten once to the required value, wait a few minutes, and tighten again	15 (21.7%)	97 (55.4%)	68 (39.3%)	180 (43.2%)
Tighten once to the required value, 1 week later patient revisits for re-tightening	23 (33.3%)	32 (18.3%)	34 (19.7%)	89 (21.3%)
Tighten more than once to the required torque without waiting	5 (7.2%)	13 (7.4%)	20 (11.6%)	38 (9.1%)
Tighten to the required value, loosen, and tighten again to the required value	5 (7.2%)	7 (4%)	9 (5.2%)	21 (5%)
Total	69 (100%)	175 (100%)	173 (100%)	417 (100%)

Pearson chi-square $p = .000$

TABLE 3 Percentage of occurrence of screw loosening for dentists using torque-limiting devices for abutment tightening (answer C, question 4) and waiting between tightening time points (answers B or C for question 10).

Response	N	%
Never	16	6.61
Less than once a year	140	57.8
3–4 times a year	65	26.8
More than 5 times a year	19	7.8
NAs	2	0.8

these findings, it can be beneficial to emphasize the effect of tightening speed when educating dentists or dental students to activate toggle-type TLDs at a slower speed, preferably within the range of 4–5.2s. This slower activation speed can contribute to more accurate and reliable results when using toggle-type TLDs (McCracken et al., 2010; Standlee et al., 2002).

The results of this survey showed that the most preferred protocol for screw tightening was waiting a few minutes after first tightening followed by the second tightening. This result is consistent with the results of the previous studies (Kim et al., 2011; Kim & Lim, 2020; Paepoemsin et al., 2016; Sammour et al., 2019; Varvara et al., 2020; Wadhvani et al., 2021). Despite tightening protocol recommendations in some studies, such as waiting for 10min between two tightening points (Siamos et al., 2002) or using a sequence tightening of tightening, loosening, and tightening again (Alnasser et al., 2021; Breeding et al., 1993; Winkler et al., 2003), previous studies indicated that waiting times had no significant effect on screw loosening (Alnasser et al., 2021; Bacchi et al., 2013; Khalili et al., 2019). Thus, a definitive recommendation for the optimal screw tightening protocol is still lacking in the literature. The present study demonstrated that over 50% of respondents, regardless of whether they used various time intervals between tightening time points, did not have a waiting time, loosened and retightened, or retightened simultaneously, mostly experienced screw loosening less than once per year. This finding

TABLE 4 Percentage of occurrence of screw loosening for dentists using torque-limiting devices for abutment tightening (answer C, question 4) and those tightening only once or more than once without waiting, or initially tightening, then loosening and tightening again (answers A, D, or E, question 10).

Response	N	%
Never	14	12
Less than once a year	63	54.3
3–4 times a year	31	26.7
More than 5 times a year	5	4.3
NAs	3	2.6

suggests that various tightening protocols may not significantly affect the observed rate of screw loosening. It can be postulated that only one tightening protocol may not be applicable to all situations. Several factors, including the type of screw material, implant system, tightening value, preload value, aging, and intraoral conditions, could collectively influence the occurrence of screw loosening.

In the present study, the respondents were categorized based on their routine practice or specialty-of-interest, with a considerable number of clinicians performing prosthodontic work. Within this survey's limitations, a direct comparison was made among dentists, who focus on different fields by classifying the respondents according to their interest in specialties and direct responses. The study findings revealed a deficiency in knowledge among dentists, regardless of their specialty, indicating no association between specialty-of-interest and knowledge-based questions related to calibration, torque value, the term "preload," and awareness of the tightening speed's effect on TLD performance. Conversely, the study findings showed variations in user preferences, particularly for the TLD usage and screw tightening protocols. This outcome aligns with the expectations, as diverse specialties may inherently employ TLDs in distinct manners; for instance, prosthodontists primarily use TLDs for abutment tightening, while surgeons use TLDs predominantly for surgical placement.

This study provides insights for torque wrench manufacturers and educators to consider developing training programs and spreading knowledge in this area. The results of this study can shed light on important aspects of TLD usage, including knowledge gaps, differences in TLD-related preference of dentists with varied specialty-of-interests, and calibration practices. Focusing on improving knowledge in future efforts can lead to improved patient care and reduced complications associated with the incorrect use of TLDs. The survey's clinical relevance highlights the importance of ongoing education in implant dentistry, particularly concerning calibration standards and torque application. While calibration frequency did not significantly impact screw loosening, proper torque reading and adherence to specialty-specific tightening protocols remain crucial for ensuring implant stability and favorable patient outcomes. These findings emphasize the importance of standardized practices and continued professional development in dental implant procedures.

CONCLUSIONS

Within the limitations of this survey, following conclusions could be drawn:

1. A considerable number of dentists lacked the knowledge of the ISO-6789 standards for toggle-type TLDs in terms of calibration. A notable difference between the current study and the US-based survey is that European clinicians calibrated their TLDs more frequently (24%) compared with their US colleagues (6%).
2. Calibration, whether conducted or not, did not have a significant effect on the frequency of screw loosening.
3. Most beam-type TLD using dentists read the torque values at the correct location on beam-type TLDs.
4. There was no significant association between the specialty-of-interest and the knowledge on calibration, the term "preload," and on the awareness of tightening speed's effect.
5. The dentists who perform prosthodontic work prefer to wait a few minutes between tightening time points, while clinicians who perform implant surgery mostly wait one week between two tightening points.
6. In each tightening protocol, the predominantly observed frequency of screw loosening was less than once per year. More than 50% of respondents, regardless of the variation in intervals between tightening or the specific tightening protocols used, experienced screw loosening less than once per year.

AUTHOR CONTRIBUTIONS

B.Y and P.K. conceived the study design; P.K and S.A. collected the data; C.K., B.Y., and P.C. analyzed the data; and P.C. and P.K. led the writing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study is exempt from ethics approval with the case number of Req-2021-01045, from Swissethics commission.

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REFERENCES

- Albayrak, H., Gumus, H. O., Tursun, F., Kocaagaoglu, H. H., & Kilinc, H. I. (2017). Accuracy of torque-limiting devices: A comparative evaluation. *The Journal of Prosthetic Dentistry*, 117, 81–86. <https://doi.org/10.1016/j.prosdent.2016.07.005>
- Alnasser, A. H., Wadhvani, C. P. K., Schoenbaum, T. R., & Kattadiyil, M. T. (2021). Evaluation of implant abutment screw tightening protocols on reverse tightening values: An in vitro study. *The Journal of Prosthetic Dentistry*, 125, 486–490. <https://doi.org/10.1016/J.PROSDENT.2020.02.035>
- Bacchi, A., Consani, R. L. X., Mesquita, M. F., & Dos Santos, M. B. F. (2013). Effect of framework material and vertical misfit on stress distribution in implant-supported partial prosthesis under load application: 3-D finite element analysis. *Acta Odontologica Scandinavica*, 71, 1243–1249. <https://doi.org/10.3109/00016357.2012.757644>
- Binon, P. P. (2000). Implants and components: Entering the new millennium. *The International Journal of Oral & Maxillofacial Implants*, 15, 76–94.
- Breeding, L. C., Dixon, D. L., Nelson, E. W., & Tietge, J. D. (1993). Torque required to loosen single-tooth implant abutment screws before and after simulated function. *The International Journal of Prosthodontics*, 6, 435–439.
- Goheen, K. L., Vermilyea, S. G., Vossoughi, J., & Agar, J. R. (1994). Torque generated by handheld screwdrivers and mechanical torquing devices for osseointegrated implants. *The International Journal of Oral & Maxillofacial Implants*, 9, 149–155.
- Goldstein, G., Ghoulal, B., & Abdullah, S. (2020). An in vitro assessment of the accuracy of new and in-use torque-limiting devices. *The Journal of Prosthetic Dentistry*, 124, 716–719. <https://doi.org/10.1016/j.prosdent.2019.09.019>
- Gutierrez, J., Nicholls, J. I., Libman, W. J., & Butson, T. J. (1997). Accuracy of the implant torque wrench following time in clinical service. *The International Journal of Prosthodontics*, 10, 562–567.
- Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., Kirby, J., Duda, S. N., & REDCap Consortium. (2019). The REDCap consortium: Building an International Community of Software Platform Partners. *Journal of Biomedical Informatics*, 95, 103208. <https://doi.org/10.1016/J.JBI.2019.103208>
- Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics*, 42, 377–381. <https://doi.org/10.1016/J.JBI.2008.08.010>
- Huang, Y., & Wang, J. (2019). Mechanism of and factors associated with the loosening of the implant abutment screw: A review. *Journal of Esthetic and Restorative Dentistry*, 31, 338–345. <https://doi.org/10.1111/JERD.12494>

- ISO 6789-1. (2017). Assembly tools for screws and nuts – hand torque tools – part 1: Requirements and methods for design conformance testing and quality conformance testing: minimum requirements for declaration of conformance. https://webstore.ansi.org/standards/iso/iso67892017?msclid=c6a2847f2ea31f9d541de0d16aabd7f2&utm_source=bing&utm_medium=cpc&utm_campaign=Campaign%20%231&utm_term=ISO%206789-1&utm_content=ISO-20K%2B
- ISO 6789-2. (2017). Assembly tools for screws and nuts – hand torque tools – part 2: Requirements for calibration and determination of measurement uncertainty. <https://webstore.ansi.org/standards/iso/iso67892017-1650488>
- Jacobs, N., Seghi, R., Johnston, W. M., & Yilmaz, B. (2022). Displacement and performance of abutments in narrow-diameter implants with different internal connections. *The Journal of Prosthetic Dentistry*, 127, 100–106. <https://doi.org/10.1016/J.PROSDENT.2020.11.008>
- Kanawati, A., Richards, M. W., Becker, J. J., & Monaco, N. E. (2009). Measurement of clinicians' ability to hand torque dental implant components. *The Journal of Oral Implantology*, 35, 185–188. <https://doi.org/10.1563/1548-1336-35.4.185>
- Khalili, M., Luke, A., El-Hammali, H., DiPede, L., & Weiner, S. (2019). Efficacy of several retightening protocols for maintaining clamping force in the implant-abutment joint: An in vitro pilot study. *The International Journal of Oral & Maxillofacial Implants*, 34, 1084–1090. <https://doi.org/10.11607/JOMI.7426>
- Kim, K. S., & Lim, Y. J. (2020). Axial displacements and removal torque changes of five different implant-abutment connections under static vertical loading. *Materials*, 13, 699. <https://doi.org/10.3390/MA13030699>
- Kim, K. S., Lim, Y. J., Kim, M. J., Kwon, H. B., Yang, J. H., Lee, J. B., & Yim, S. H. (2011). Variation in the total lengths of abutment/implant assemblies generated with a function of applied tightening torque in external and internal implant-abutment connection. *Clinical Oral Implants Research*, 22, 834–839. <https://doi.org/10.1111/J.1600-0501.2010.02063.X>
- Kim, S. K., Koak, J. Y., Heo, S. J., Taylor, T. D., Ryoo, S., & Lee, S. Y. (2012). Screw loosening with interchangeable abutments in internally connected implants after cyclic loading. *The International Journal of Oral & Maxillofacial Implants*, 27, 42–47.
- L'Homme-Langlois, E., Yilmaz, B., Chien, H. H., & McGlumphy, E. (2015). Accuracy of mechanical torque-limiting devices for dental implants. *Journal of Prosthetic Dentistry*, 114, 524–528. <https://doi.org/10.1016/j.prosdent.2014.11.017>
- McCracken, M. S., Mitchell, L., Hegde, R., & Mavalli, M. D. (2010). Variability of mechanical torque-limiting devices in clinical service at a US dental school. *Journal of Prosthodontics*, 19, 20–24. <https://doi.org/10.1111/J.1532-849X.2009.00524.X>
- Mcglumphy, E. A., Mendel, D. A., & Holloway, J. A. (1998). Implant screw mechanics. *Dental Clinics of North America*, 42, 71–89.
- O'Brien, R., Wadhvani, C. P. K., Rosen, P. S., & Chung, K.-H. (2021). Validating implant torque limiting devices with a custom tool: A dental technique. *The Journal of Prosthetic Dentistry*, 125, 407–410. <https://doi.org/10.1016/j.prosdent.2020.03.003>
- Paepoemsin, T., Reichart, P. A., Chaijareenont, P., Strietzel, F. P., & Khongkhunthian, P. (2016). Removal torque evaluation of three different abutment screws for single implant restorations after mechanical cyclic loading. *Oral Implantology*, 9, 213–221. <https://doi.org/10.11138/ORL/2016.9.4.213>
- Sammour, S. R., Maamoun El-Sheikh, M., & Aly El-Gendy, A. (2019). Effect of implant abutment connection designs, and implant diameters on screw loosening before and after cyclic loading: In-vitro study. *Dental Materials*, 35, e265–e271. <https://doi.org/10.1016/J.DENTAL.2019.07.026>
- Siamos, G., Winkler, S., & Boberick, K. G. (2002). Relationship between implant preload and screw loosening on implant-supported prostheses. *The Journal of Oral Implantology*, 28, 67–73. [https://doi.org/10.1563/1548-1336\(2002\)028<0067:TRBIPA>2.3.CO;2](https://doi.org/10.1563/1548-1336(2002)028<0067:TRBIPA>2.3.CO;2)
- Standlee, J. P., Caputo, A. A., Chwu, M. J., & Sun, T. T. (2002). Accuracy of mechanical torque-limiting devices for implants. *The International Journal of Oral & Maxillofacial Implants*, 17, 220–224.
- Stroosnijder, E., Gresnigt, M., Meisberger, E., & Cune, M. (2016). Loss of accuracy of torque wrenches due to clinical use and cleaning procedure: Short communication. *The International Journal of Prosthodontics*, 29, 253–255. <https://doi.org/10.11607/IJP.4567>
- Vallee, M. C., Conrad, H. J., Basu, S., & Seong, W. J. (2008). Accuracy of friction-style and spring-style mechanical torque limiting devices for dental implants. *The Journal of Prosthetic Dentistry*, 100, 86–92. [https://doi.org/10.1016/S0022-3913\(08\)60154-7](https://doi.org/10.1016/S0022-3913(08)60154-7)
- Varvara, G., Sinjari, B., Caputi, S., Scarano, A., & Piattelli, M. (2020). The relationship between time of retightening and preload loss of abutment screws for two different implant designs: An in vitro study. *The Journal of Oral Implantology*, 46, 13–17. <https://doi.org/10.1563/AAID-JOI-D-18-00138>
- Wadhvani, C. P. K., O'Brien, R. T., Rosen, P. S., & Chung, K.-H. (2020). A technique to validate the accuracy of a beam-type mechanical torque limiting device. *The Journal of Prosthetic Dentistry*, 124, 647–652. <https://doi.org/10.1016/j.prosdent.2019.12.019>
- Wadhvani, C., Rosen, P., Yang, G., Hu, W., Schoenbaum, T., Linkevicius, T., Iyer, S., Hess, T., Kattadiyil, M., & Chung, K.-H. (2021). Survey of dental clinicians for attitude and use of torque-limiting devices. *The International Journal of Oral & Maxillofacial Implants*, 36, 538–545. <https://doi.org/10.11607/JOMI.8590>
- Winkler, S., Ring, K., Ring, J. D., & Boberick, K. G. (2003). Implant screw mechanics and the settling effect: Overview. *The Journal of Oral Implantology*, 29, 242–245. [https://doi.org/10.1563/1548-1336\(2003\)029<0242:ISMATS>2.3.CO;2](https://doi.org/10.1563/1548-1336(2003)029<0242:ISMATS>2.3.CO;2)
- Yilmaz, B., L'Homme-Langlois, E., Beck, F. M., & McGlumphy, E. (2015). Accuracy of mechanical torque-limiting devices for dental implants after clinical service. *The Journal of Prosthetic Dentistry*, 114, 378–382. <https://doi.org/10.1016/j.prosdent.2015.03.003>

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