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Assessment of Maximum Torque in Implant-Supported Prostheses: A Pilot Laboratory Study

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Abstract

Background/Objectives: the precise application of torque during prosthetic screw tightening is essential to the long-term success and mechanical stability of implant-supported restorations. This study aimed to evaluate the influence of practitioner experience, glove material, screwdriver length, and hand moisture on the maximum torque value (MTV) generated during manual tightening. Methods: thirty participants, comprising 10 experienced professors and 20 senior dental students, performed tightening tasks under six hand conditions (nitrile gloves, latex gloves, and bare hands, each in dry and wet environments) using two screwdriver lengths (21 mm and 27 mm). The torque values were measured using a calibrated digital torque meter, and the results were analyzed using a linear mixed model. Results: professors applied significantly higher torque than students (16.92 Ncm vs. 15.03 Ncm; $p = 0.008$). Nitrile gloves yielded the highest torque (17.11 Ncm), surpassing bare hands significantly ($p = 0.003$). No statistically significant differences were found for screwdriver length ($p = 0.12$) or hand moisture ($p = 0.11$). Conclusions: these findings underscore the importance of clinical proficiency and glove material in torque delivery, providing evidence-based insights to enhance procedural reliability and training standards in implant prosthodontics.

Keywords: dental prosthesis; implant-supported; dental prosthesis retention; torque; biomechanics; dental implants

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1. Introduction

Over recent decades, implant dentistry has advanced dramatically, becoming a predictable treatment for tooth replacement [1–3]. Innovations such as osseointegration, new biomaterials like titanium and zirconia, improved implant surfaces, and immediate loading protocols have enhanced implant stability and patient satisfaction [4–8]. Additionally, minimally invasive digital-guided techniques contribute to more precise and predictable outcomes [9–12].

The prosthetic approach—cemented vs. screw-retained—critically influences the long-term success of implant restorations. Cemented restorations offer aesthetic advantages but carry risks of cement-induced peri-implantitis. In contrast, screw-retained restorations facilitate retrievability and maintenance but risk screw loosening or fractures due to incorrect torque application [13–20]. Several mechanical and clinical factors, including screw design, material properties, and occlusal habits, can impact prosthetic stability [21,22]. Consequently, accurate torque application, generally recommended at around 15–35 Ncm, depending on the prosthetic components, is critical for minimizing these risks [23,24]. Clinicians must balance torque to avoid complications: insufficient preload leads to microgaps and biological risks, while excessive torque can cause mechanical failures [25–31].

Manual torque application remains widely practiced despite notable variability influenced by the clinician experience, ergonomic design of instruments, and clinical environmental factors. Less experienced clinicians often deviate from manufacturer-recommended torque values, and glove material or moisture may further compromise manual control [22,32,33].

Although mechanical torque-limiting devices (e.g., spring- and friction-style wrenches) offer improved control, their long-term accuracy may deteriorate due to sterilization, aging, and wear. Repeated autoclaving and extended clinical use have been shown to lead to loss of calibration and increasingly inconsistent torque output [34,35].

This reinforces the need for regular validation protocols and highlights the risks of relying solely on uncalibrated manual devices. Furthermore, aged torque devices may deviate significantly from their intended torque values even within the same brand or model, increasing the risk of mechanical complications during prosthetic screw tightening [36,37]. Despite the availability of such tools, manual tightening remains common due to its simplicity and practicality. However, this technique is highly sensitive to operator- and procedure-related factors, highlighting the importance of understanding their effect on torque accuracy in implant-supported prostheses.

While the existing literature has examined these variables in isolation, there remains a lack of research exploring how these factors interact under standardized test conditions. The present study addresses this gap by evaluating the combined influence of glove type, hand moisture, screwdriver length, and user experience on torque delivery. Recent studies have emphasized the importance of assessing these variables in combination rather than separately to better reflect real-world scenarios and improve clinical applicability. By identifying which procedural and operator-related factors have the greatest impact on torque output, this study aims to inform more reliable clinical protocols and improve the long-term success of implant-supported prostheses.

2. Materials and Methods

This in vitro experiment investigated manual torque performance under varying clinical conditions, with particular attention to user experience and environmental variables.

This study used implant analogs (RT Implant analog, Straumann® Basel, Switzerland, Ref. 036.0102) embedded in blocks composed of aluminum alloy frames filled with type III dental stone (Pro-Solid Super®, Whip Mix Corporation, Louisville, KY, USA), selected for their mechanical stability and repeatability (Figure 1). A straight abutment (Straumann® Variobase® RT, Ref. 037.1201, Straumann Holding AG, Basel, Switzerland) with a prosthetic screw (Straumann® Variobase® RT, Ref. 036.3110, Straumann Holding AG, Basel, Switzerland) was screwed in the implant, creating a single-unit restoration simulation.

Manual torque was applied using two types of SCS screwdrivers—medium (21 mm, Ref. 046.401) and long (27 mm, Ref. 046.402)—representing common options in clinical scenarios. These tools were selected based on their ergonomics in the posterior and anterior regions, respectively.

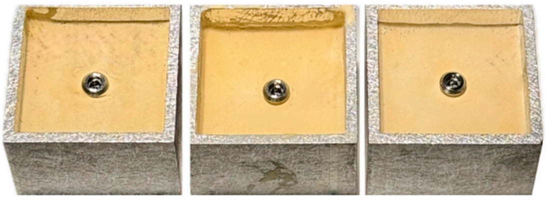

Figure 1. Worktables used in the study showing implant analogs embedded in type III dental stone within aluminum alloy frames. This setup was used to simulate clinical conditions for torque measurement while providing mechanical stability during manual screw tightening procedures.

Three-hand conditions were evaluated: bare hands, latex gloves, and nitrile gloves, each tested in both dry and wet conditions. The wet environment was simulated with water application to mimic intraoral moisture (Figure 2).

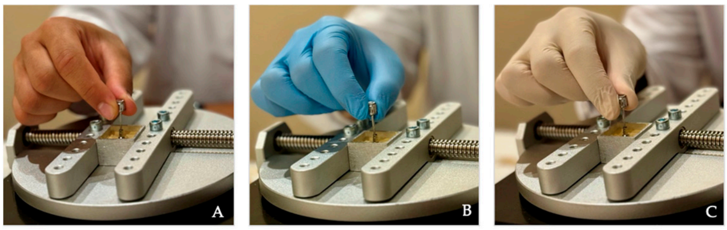

Figure 2. Hand condition demonstration: (**A**) bare hand, (**B**) nitrile glove, (**C**) latex glove.

While bare-hand torque application is not advised in clinical practice due to infection control protocols, it was included to test grip performance under non-standard but real-life conditions.

The experiment also considered user experience as a critical factor. Participants were divided into two groups: dental students (4th and 5th year, the clinical years of the graduation) and professors. This distinction allowed for comparison between novice and advanced users, evaluating how clinical experience might influence torque control.

Based on a presumable population of 4th and 5th-year dental students and professors with experience in oral rehabilitation within Portugal's dental schools (eventual number of 400), a minimum sample size of 29 participants was calculated using an online sample size calculator. This ensured a 95% confidence level with a 5% margin of error, assuming a population proportion of 2% in a universe of 400 eligible individuals. This calculation guaranteed that the real value of the data would be within ±5% of the measured or surveyed value. The number of participants in this study was similar to this minimum requirement, thus meeting the statistical sampling needs for reliability and accuracy.

Torque was measured using a digital torque meter (PCE Instruments™, PCE-CTT 2, Tobarra, Spain), capable of capturing peak torque values in Newton centimeters (Ncm) with high accuracy (0.098 Ncm) (Figure 3). This device was calibrated by a certified laboratory of metrology and calibration (Servincal S.A.©, Valladolid, Spain) under ISO/IEC 17025:2017 on 9 November 2021 and used only in previous pilot research studies on the same issue.

All participants underwent a brief training session by a professor of Oral Rehabilitation on proper torque application techniques using the provided screwdrivers under different conditions.

The data were collected after each trial, and the order of testing was randomized to minimize the influence of fatigue or learning effects.

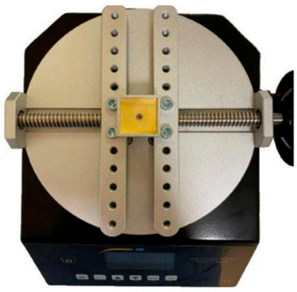

Figure 3. Digital torque meter setup (PCE-CTT 2).

Participants were grouped and sub-grouped as follows (Figure 4):

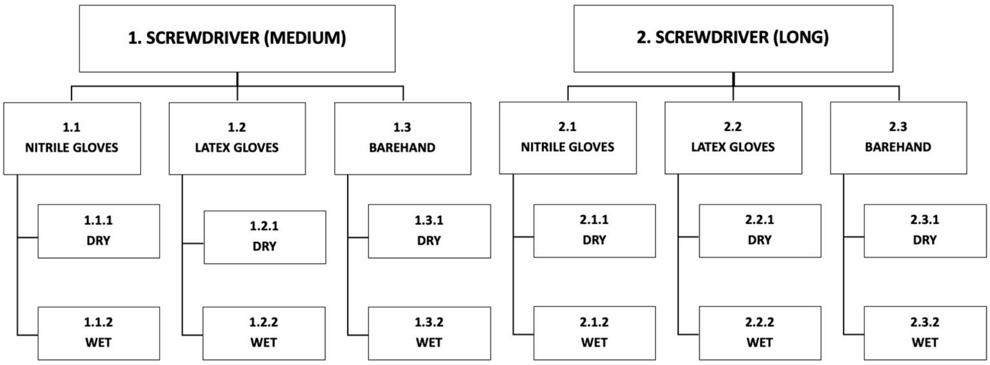

Figure 4. Distribution of the "users" into groups and subgroups among the various conditions.

Group 1: Medium screwdriver
Subgroups: bare hands, latex gloves, nitrile gloves (dry and wet conditions);
Group 2: Long screwdriver
Subgroups: bare hands, latex gloves, nitrile gloves (dry and wet conditions).

A linear mixed model (LMM) was used to analyze the MTV values obtained during the manual tightening of prosthetic screws. The dependent variable was MTV. Fixed effects included the screwdriver (long and short), glove type (nitrile, latex, and bare hands), surface condition (wet vs. dry), and experience level (professor vs. student). The technician ($n = 30$; 10 professors and 20 students) was modeled as a random effect, as each participant performed repeated measures across all conditions.

The initial diagnostics showed that the raw MTV values violated the assumptions of normality. Therefore, the natural logarithm of the MTV was computed and used as the dependent variable. The model assumptions were reassessed using residual plots and were found to be reasonably satisfied after transformation.

Interaction terms between fixed effects were initially included, but none reached statistical significance ($p > 0.05$). Consequently, only main effects were retained in the final model. Estimated marginal means (EMMeans) were calculated, and Bonferroni-adjusted pairwise comparisons were used for post-hoc analysis where appropriate. All analyses were conducted using SPSS Statistics (version 28.0).

The study protocol was approved by the Ethics Committee for Health of the University (CES), and all participants provided informed consent before participation.

3. Results

Thirty participants were selected for this study, including 10 professors (dedicated to oral rehabilitation and oral surgery with clinical experience in implant procedures) and 20 undergraduate dental students from the fourth and fifth years (evenly distributed) of the Integrated Master in Dental Medicine (MIMD) program. All participants were right-handed.

This diverse sample enabled a comprehensive comparison of manual torque application across different levels of clinical experience.

Following participant characterization, maximum torque values were analyzed for both groups—professors and students—under different test conditions, as detailed in the previous section (Table 1, Table 2 and Tables S1–S6).

Table 1. Maximum torque values achieved by professors (Prof-X) during manual tightening procedures. The table compares results for" long" and "medium" screwdrivers under various conditions (nitrile gloves, latex gloves, and bare hands, both dry and wet).

TIMESTAMP	PROFESSORS (n)	MEDIUM SCREWDRIVER (Ncm)						LONG SCREWDRIVER (Ncm)					
		Nitrile		Latex		Bare Hand		Nitrile		Latex		Bare Hand	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
06.05.25 9–9:30	**Prof-1**	12.9	20.0	18.8	10.9	11.4	10.2	14.8	11.0	11.1	11.7	8.2	11.8
06.05.25 9:30–10	**Prof-2**	14.6	15.3	21.2	12.1	15.8	16.0	22.5	19.2	17.6	19.4	13.8	13.3
06.05.25 10–10:30	**Prof-3**	36.0	27.8	18.7	10.7	20.8	19.7	32.3	21.3	8.2	8.6	10.9	8.9
06.05.25 10:30–11	**Prof-4**	7.3	6.6	22.4	14.8	9.6	11.7	12.3	9.7	29.3	20.8	15.3	21.8
06.05.25 11–11:30	**Prof-5**	14.6	10.7	7.4	9.6	6.4	5.6	14.1	10.8	7.3	7.4	7.9	6.0
06.05.25 11:30–12	**Prof-6**	11.7	15.8	18.3	30.1	10.9	10.1	13.5	15.6	18.3	21.4	12.3	11.4
06.05.25 14–14:30	**Prof-7**	27.0	18.4	17.8	18.0	20.2	18.4	24.1	21.2	15.0	17.5	11.1	10.4
06.05.25 14:30–15	**Prof-8**	34.5	38.2	41.0	28.9	30.5	23.1	30.5	31.1	25.0	26.4	29.8	19.6
06.05.25 15–15.30	**Prof-9**	20.1	15.7	18.1	12.6	13.5	16.3	22.0	10.8	13.6	14.5	12.7	7.8
06.05.25 15:30–16	**Prof-10**	29.4	29.4	13.6	11.7	28.7	24.5	23.5	16.1	11.3	13.8	14.0	14.1
TOTAL VALUE (Ncm)		**19.67**	**19.79**	**19.73**	**15.94**	**16.78**	**15.57**	**20.96**	**16.68**	**15.67**	**16.15**	**13.60**	**12.51**

Table 2. Maximum torque values achieved by fourth and fifth year dental students (S-X) during manual tightening procedures. The table presents torque comparisons for "long" and "medium" screwdrivers under multiple conditions (nitrile gloves, latex gloves, and bare hands, both dry and wet).

TIMESTAMP	STUDENTS		MEDIUM SCREWDRIVER (Ncm)						LONG SCREWDRIVER (Ncm)					
			Nitrile		Latex		Bare Hand		Nitrile		Latex		Bare Hand	
	n	Graduation Year	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
07.05.2025 9–9:30	**S-1**	4	16.4	14.0	24.5	16.9	12.2	9.5	16.1	19.6	13.7	24.0	11.3	10.0
07.05.2025 9:30–10	**S-2**	4	18.5	19.3	30.4	29.5	16.1	15.6	17.2	15.2	25.3	28.2	11.9	10.0
07.05.2025 10–10:30	**S-3**	4	15.6	10.1	13.8	14.8	20.0	9.9	11.8	12.3	11.1	11.9	9.4	7.5

Table 2. *Cont.*

TIMESTAMP	STUDENTS		MEDIUM SCREWDRIVER (Ncm)						LONG SCREWDRIVER (Ncm)					
			Nitrile		Latex		Bare Hand		Nitrile		Latex		Bare Hand	
	n	Graduation Year	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
07.05.2025 10:30–11	**S-4**	4	18.5	20.6	18.6	16.2	13.6	8.1	28.5	23.8	15.6	18.6	14.1	11.7
07.05.2025 11–11:30	**S-5**	4	16.2	11.6	21.5	18.0	9.2	5.7	17.1	14.9	21.6	15.5	13.2	8.5
07.05.2025 11:30–12	**S-6**	4	8.3	13.3	13.7	14.8	8.1	17.3	10.8	9.4	9.5	14.4	12.6	14.8
07.05.2025 14–14:30	**S-7**	4	9.8	10.8	12.1	10.8	7.6	6.5	9.7	11.0	10.8	12.1	4.6	7.0
07.05.2025 14:30–15	**S-8**	4	16.6	9.1	9.1	8.6	8.1	15.5	24.2	11.5	14.8	7.3	11.9	6.7
07.05.2025 15–15:30	**S-9**	4	21.2	35.0	17.2	17.7	24.1	25.3	22.4	28.2	14.9	25.3	15.3	27.6
07.05.2025 15:30–16	**S-10**	4	14.6	20.1	15.6	17.4	11.4	9.9	26.0	13.9	17.5	11.3	19.9	15.1
08.05.2025 9–9:30	**S-11**	5	14.8	12.9	22.1	14.0	17.4	13.2	6.9	9.8	12.2	10.6	11.6	10.2
08.05.2025 9:30–10	**S-12**	5	13.3	10.2	18.8	11.6	6.7	6.8	11.6	6.1	8.8	8.3	7.4	9.2
08.05.2025 10–10:30	**S-13**	5	12.6	10.9	11.4	7.5	4.4	14.3	5.4	7.0	9.3	5.8	5.7	5.6
08.05.2025 10:30–11	**S-14**	5	10.1	13.8	6.8	12.4	7.6	5.6	12.2	11.3	5.8	6.2	13.2	15.4
08.05.2025 11–11:30	**S-15**	5	11.8	14.1	15.3	16.1	18.3	18.9	14.2	11.8	12.4	6.9	18.9	15.2
08.05.2025 11:30–12	**S-16**	5	6.3	8.7	5.1	6.8	11.4	5.4	14.6	8.0	4.4	8.0	11.2	7.5
08.05.2025 14–14:30	**S-17**	5	10.8	6.9	13.2	5.9	22.9	15.0	15.3	9.1	16.1	11.3	18.5	15.5
08.05.2025 14:30–15	**S-18**	5	23.5	39.3	11.1	37.8	28.9	28.3	24.4	26.0	10.4	20.5	22.3	40.9
08.05.2025 15_15:30	**S-19**	5	43.5	28.7	16.9	23.0	24.8	23.2	40.5	24.3	18.4	23.9	16.4	16.1
08.05.2025 15:30–16	**S-20**	5	16.6	13.2	23.9	23.0	40.8	12.3	19.6	19.7	28.7	10.3	20.8	14.6
TOTAL VALUE (Ncm)			**15.94**	**16.12**	**16.05**	**16.14**	**15.68**	**13.31**	**17.42**	**14.64**	**14.06**	**14.02**	**13.51**	**13.45**

This analysis aimed to explore the impact of user experience, glove type, and external environmental factors on manual torque application.

The following subsections describe the main findings from a linear mixed model analysis with participant as a random effect. Where appropriate, descriptive tables and figures have been retained to support interpretation.

3.1. User Experience

The linear mixed model indicated a statistically significant main effect of user experience on maximum torque values ($p < 0.05$). Professors applied a mean torque of 16.92 Ncm, while students applied a mean torque of 15.03 Ncm, and the difference is visually illustrated in Figure 5 for improved clarity and interpretation.

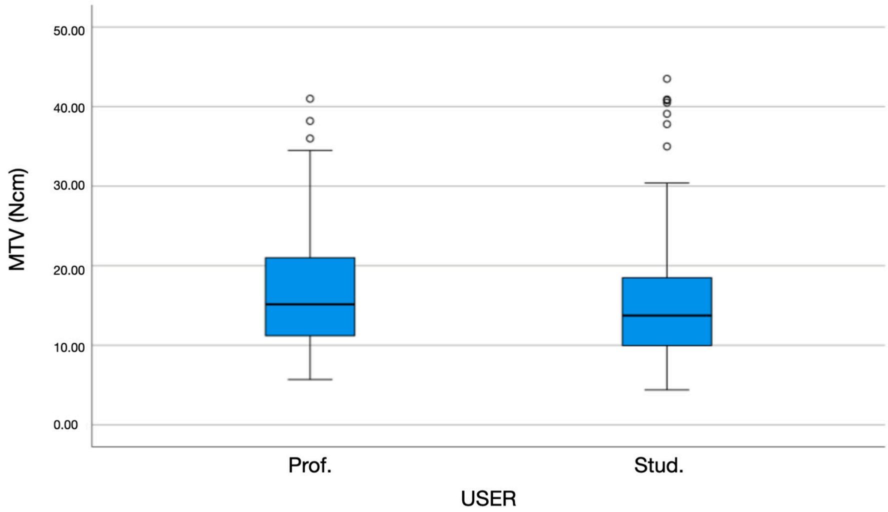

Figure 5. Boxplot illustrating the distribution of maximum torque value (MTV) in Newton centimeters (Ncm) between different user groups (professors and students). This visual representation highlights the variation and central tendency of torque values across these groups, providing insight into the impact of clinical experience on manual torque application.

3.2. Glove Type

Glove type was a significant predictor of applied torque ($p < 0.05$). Post-hoc comparisons revealed that the torque was significantly higher when using nitrile gloves (17.11 Ncm) compared to bare hands (14.20 Ncm). No significant differences were observed between nitrile and latex gloves (15.67 Ncm) or between latex gloves and bare hands.

Given the significant differences observed between students and professors, it was valuable to further analyze the maximum torque value (MTV) for each group separately. Among students, the highest torque was observed when using nitrile gloves (16.03 Ncm), followed by latex gloves (15.07 Ncm) and bare hands (13.99 Ncm). For professors, torque values were also highest with nitrile gloves (19.28 Ncm), followed by latex (16.87 Ncm) and bare hands (14.62 Ncm). Boxplots visualizing these differences are presented in Figures 6 and 7.

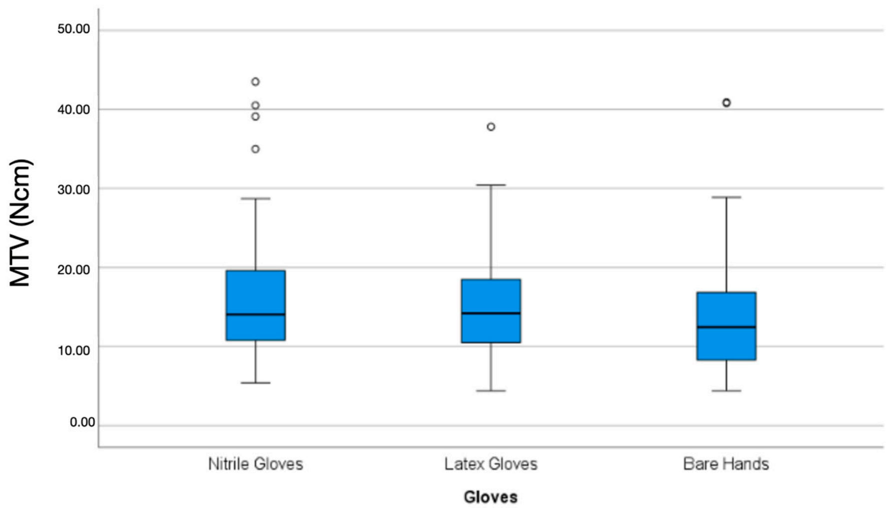

Figure 6. Boxplot illustrating the distribution of maximum torque value (MTV) for students using different "glove types" (nitrile, latex, and bare hands). This visual representation highlights the spread and central tendency of MTV values across the groups of students.

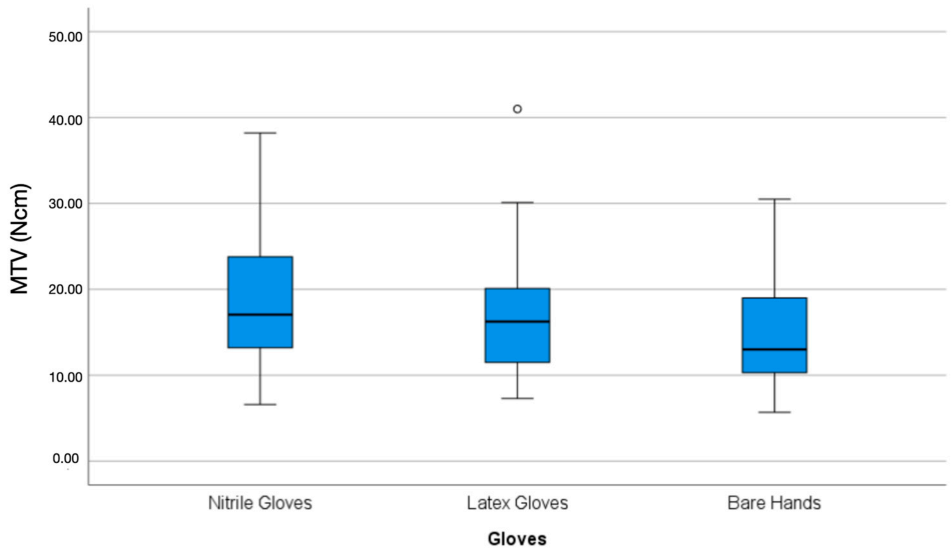

Figure 7. Boxplot illustrating the distribution of maximum torque value (MTV) for professors using different "glove types" (nitrile, latex, and bare hands). This boxplot emphasizes the differences in MTV values between the groups and helps visualize the effect of "gloves" on torque application for professors.

3.3. Moisture Condition

Moisture condition (wet vs. dry) did not significantly affect torque values according to the linear mixed model ($p > 0.05$). The torque was slightly higher under dry conditions (16.21 Ncm) compared to wet conditions (15.11 Ncm), but this difference was not statistically significant. Figure 8 shows the distribution of the data under both conditions.

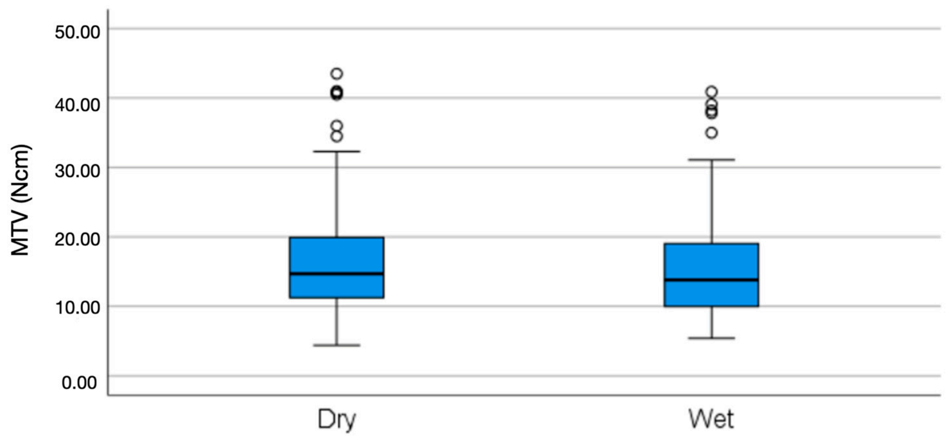

Figure 8. Boxplot comparing the MTV distributions for "moisture conditions".

3.4. Screwdriver Length

No statistically significant effect of screwdriver length (long vs. short) was observed on the applied torque values ($p > 0.05$). The torque values were slightly higher with medium-length screwdrivers (16.33 Ncm) compared to long screwdrivers (14.99 Ncm), but this difference was not significant. This pattern was consistent across participant groups and glove conditions. A boxplot illustrating the distribution of torque values by screwdriver length is shown in Figure 9.

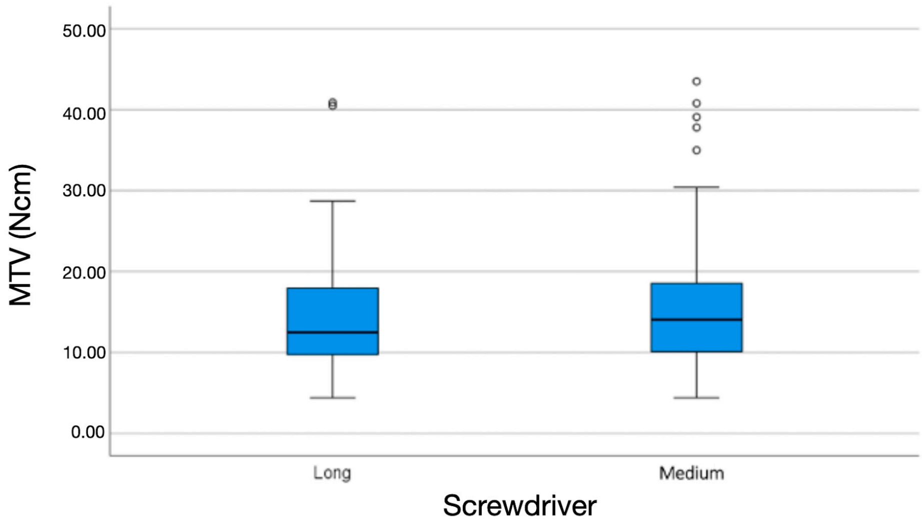

Figure 9. Boxplot comparing the MTV distributions for "Screwdriver lengths".

These findings confirm that practitioner experience and the type of gloves used play a statistically significant role in the manual application of torque during prosthetic screw tightening. In contrast, screwdriver length and moisture condition did not significantly influence the outcomes.

4. Discussion

The accurate application of torque in dental implantology is essential for ensuring the long-term stability and success of implant-supported prostheses. This study aimed to assess the maximum torque applied during the manual tightening of prosthetic screws, with a particular focus on how user experience and procedural conditions—such as glove type, moisture, and screwdriver length—influence torque performance.

Experience was one of the most influential variables. In this study, professors consistently applied higher maximum torque values (MTV) compared to students. This is aligned with the findings of Alikhasi et al. [22] who reported that clinicians with more experience apply torque closer to or beyond the recommended limits. Similarly, Kanawati et al. [38] demonstrated significant variability between experienced and less experienced clinicians, confirming that practice and muscle memory play an essential role. In line with this, Parnia et al. [39] also found that professors performed better in torque consistency than postgraduate students. Therefore, our results are strongly aligned with the previous literature that emphasizes experience as a determining factor in torque control.

Glove type was also a statistically significant variable. In particular, nitrile gloves allowed for greater torque application than latex gloves or bare hands, especially in the experienced group. This finding is aligned with the ergonomic studies by Zare et al. [33] and Mylon et al. [40], which reported that glove material and fit can significantly affect the grip and fine motor control. However, in our student subgroup, glove type had no statistically significant effect. This contrasts with Sung [41], who noted glove-related grip differences even among general operators. This divergence may be explained by previously reported differences in grip control and proprioceptive adaptation between novice and experienced clinicians. According to Nishiuchi et al. [32] experienced users better modulate torque based on tool characteristics and tactile input. Similarly, Jaarda et al. [42] and Parnia et al. [39] have shown that less experienced practitioners apply more inconsistent torque, suggesting a less refined motor response when faced with subtle ergonomic variables such as glove type.

It is important to note that participants used gloves that they normally wear in their daily clinical practice, ensuring proper fit and comfort during the experiments. This approach helped minimize the potential variability in torque application due to glove fit.

On the other hand, screwdriver length did not significantly influence the torque performance in our results. This is consistent with Alikhasi et al. [22], who also observed no statistically significant difference between short and long screwdrivers when torque was applied manually. Similarly, Jaarda et al. [42] Haack et al. [43] and showed that torque is more dependent on user consistency than tool geometry under manual conditions.

Moisture conditions (wet vs. dry) also did not show a significant impact on torque values in our study. While Zare et al. [33] highlighted the negative impact of wet gloves on manual precision, we did not observe a significant effect. This may be due to the controlled lab setting, where real intraoral challenges such as visibility, saliva, and patient movement were not present. Therefore, further clinical testing may be needed to assess this parameter. The absence of statistically significant differences for hand moisture and screwdriver length may offer reassurance to clinicians that these variables, under standard clinical conditions, may not critically impair torque control. This could simplify training protocols and reinforce the reliability of manual torque delivery regardless of minor ergonomic or environmental changes. However, given the controlled nature of this study, caution is advised when extrapolating these findings to more complex intraoral scenarios.

This study also has limitations. It was conducted in a preclinical environment using Type III plaster, which does not replicate bone quality, tissue resistance, or intraoral access limitations, although it closely simulates the osseointegration of a dental implant with no movement of the fixture.

In addition to material differences, the in vitro setup cannot replicate real intraoral constraints such as restricted mouth opening, limited access to posterior regions, soft tissue interference, presence of saliva or blood, and unpredictable patient movement. Saliva, for example, has viscoelastic and lubricative properties that differ significantly from water, potentially affecting grip and tactile control. In this study, moisture simulation was performed using tap water rather than artificial saliva, which is acknowledged as a methodological limitation. These factors can influence the tool angulation, visual access, and torque consistency during screw tightening. Therefore, while the plaster model provides mechanical stability, it lacks the spatial and biological complexity of the actual oral environment.

As highlighted by Barone et al. [25] in vivo, torque can be influenced by many factors not reproducible in vitro. Additionally, participant characteristics, such as body mass index, gender, age, hand size, grip strength, or fatigue, were not recorded in this study due to this limited sample size, although they may influence torque output. The absence of these variables is acknowledged as a limitation. Future studies may incorporate these parameters in subgroup or correlation analyses using larger and stratified samples designed to explore such associations.

Although the sample size was estimated based on a population-level approach with acceptable confidence and margin of error, it did not include power analysis based on anticipated effect sizes for multifactorial interactions. This limitation is acknowledged, and the data generated in this study will support future power calculations to ensure adequate sensitivity for detecting interaction effects.

Despite these limitations, our study offers practical insights. Similar to the conclusions of Yilmaz et al. [44] and Alsubaiy [27], our findings support that user variability is a key contributor to torque inconsistency and potentially to screw loosening. Identifying which variables truly matter, such as clinician experience and glove material, can help inform training protocols and improve clinical predictability.

Future studies should be conducted using calibrated torque devices with different mechanisms and should also evaluate how repeated use and time affect the stability and reliability of the applied torque. In addition, clinical investigations are necessary to assess torque delivery during live implant procedures, where variables such as saliva, patient movement, and restricted access can influence outcomes. Comparisons across different implant systems and screwdriver brands may also reveal whether system-specific ergonomics affect torque consistency. Additionally, continued innovation in biomaterials—including ceramic coatings and polymeric composites—may also enhance prosthetic performance and torque transmission in future implant systems [45,46].

5. Conclusions

This study provides valuable insights into the factors affecting maximum torque application in implant dentistry. The experience level significantly influenced the performance, with professors achieving higher torque values than students, highlighting the role of clinical proficiency in torque application.

Among the tested variables, the glove type had a notable impact, with nitrile gloves producing higher torque values than bare hands, reinforcing their advantage in clinical practice.

However, the screwdriver length and hand moisture conditions showed no significant effect, suggesting that these factors may not be as critical as previously assumed.

These findings emphasize the importance of structured training and evidence-based guidelines to improve torque precision and minimize risks such as screw loosening and prosthetic failure. Incorporating these insights into clinical education and practice can enhance manual dexterity, procedural consistency, and long-term implant success.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/prosthesis7040083/s1, Table S1: Complete torque data table of average maximum torque values under the studied conditions; Table S2: Mean maximum torque values (Ncm) of professors and students; Table S3: Mean maximum torque values (Ncm) across glove types (nitrile, latex, bare hands), pooled across all participants; Table S4: Mean maximum torque values (Ncm) for each glove type, stratified by user experience (students vs. professors); Table S5: Comparison of mean torque values (Ncm) under dry and wet hand conditions; Table S6: Comparison of mean torque values (Ncm) between long and medium screwdriver lengths.

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Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body Mass Index
CES	Ethics Committee for Health
FMD-UCP	Faculty of Dental Medicine—Universidade Católica Portuguesa
MIMD	Integrated Master in Dental Medicine
MTV	Maximum torque value
Ncm	Newton centimeter (unit of torque)
PCE-CTT 2	Model of the digital torque meter used (PCE Instruments™)
RT	Regular TorcFit™ (Straumann's connection system)
SCS	Screw Carrying System

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