Factors Affecting Torque of Beam Type Implant Torque Wrench

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Abstract

Background: Screw breakage and loosening are the most common mechanical complications in implant treatment. One of the causes is the excess or deficiency of the screw tightening torque; thus, the use of a torque wrench is a prerequisite for achieving an accurate tightening torque. Therefore, we focused on the beam-type torque wrenches, which are the main type, to clarify the factors affecting this torque.

Results: The torque values of the beam-type torque wrenches for the eight manufacturers were measured using a torque gauge. For investigating the influence of the location of the beam placed on the scale, the measurement was performed with the scale aligned with the upper edge, center, and lower edge of the beam. Additionally, measurements were taken at 90°, 60°, and 30° to examine the effect of the angle at which the examiner read the torque value. Under each condition, a single examiner applied the recommended torque value of each manufacturer's screws five times clockwise. The average measured torque, standard deviation, bias, and coefficient of variation were calculated and compared. Equipment from six manufacturers demonstrated the best accuracy for measurements at the center of the beam (bias within ± 4%). For measurements at 90°, equipment from five manufacturers displayed the highest accuracy (bias within ± 7%), and seven showed the highest repeatability (coefficient of variation 2% or less).

Conclusion: It was recommended that the center of the beam should be aligned with the scale and read from 90°, while tightening the torque wrench. The accuracy and repeatability differed according to the manufacturer, scale width, scale line width, and beam width, while the distance between scale and beam center was related to accuracy and repeatability. Based on these results, it was suggested that a torque wrench must be selected after grasping the difference depending on the structure of the model to be used.

Background

Oral implant treatment is widely used as an option for prosthodontic treatment [1–4]. Although implant treatment has a high success rate of more than 90%, mechanical complications can occur [5], one of the most common being screw breakage and loosening [6, 7]. These can lead to problems such as damage to surrounding bone tissue and loss of osseointegration [8–12]. The factors that can cause these types\ of mechanical complications are as follows: incompatibility in connecting the implant superstructure, repeated bending moments, initial loosening of the tightened screw, insufficient screw strength, and insufficient or excessive tightening force applied to the screw [13]. In particular, the latter occurs more frequently clinically and is caused by various factors.

When fixing the implant superstructure, it is first tightened by hand; however, finally, the screws are tightened using a torque wrench. Thus, the use of a torque wrench is essential for an accurate tightening force. However, properties such as the accuracy and repeatability of torque wrenches have not been fully verified.

The torque value exerted by an industrial torque wrench is affected by the type and structure of the torque wrench and the positioning of the examiner [14]; however, the details of the torque wrench for oral implants are unknown.

This study focused on the insufficient or excessive screw tightening force, which is a typical factor of mechanical complications, and focused on the main types of beam-type torque wrenches among beam, preset, and digital types. This study aimed to contribute to the long-term prognosis of implant treatment by clarifying the factors affecting torque exertion.

Materials And Methods

2.1 Participants

Torque wrenches are broadly classified into two types: mechanical and digital; the former is further classified into the beam and preset types. Considering the global market share, the following eight beam types were selected: Ratchet (Institut Straumann Ag, Basel, Switzerland); Manual Torque Wrench Prosthetic (Nobel Biocare, Zürich-Frughafen, Switzerland); Ex Torque Wrench (Kyocera Medical Corporation, Osaka, Japan); GC Implant Re and Surgical Instrument Torque Wrench (Gc, Tokyo, Japan); Torque Ratchet Wrench (Ktc, Kyoto, Japan); Mono torque ratchet (Thommen, Grenchen, Switzerland); Torque wrench (Nippon Piston Ring Co, Saitama, Japan); and Biofix Torque wrench (Shofu, Kyoto, Japan) (Figure 1).

3.2 Measurement device

A screwdriver (Screwdriver Machine Unigrip 20 mm, Nobel Biocare, Japan) and a torque gauge (BTG36CN, Tohnichi, Japan) were fixed (Figure 2), and the torque values exerted by each torque wrench (actual measured torque values) were measured using the Latin square design.

3.2 Measurement of the torque value

The same examiner, who was experienced in implant treatment, applied the recommended torque value of each manufacturer’s prosthetic screws (target torque value) five times clockwise (Table 1). For investigating the influence of the location of the beam placed on the scale, the measurement was performed with the scale aligned with the upper edge, center, and lower edge of the beam (Figure 3). Additionally, measurements were recorded at 90°, 60°, and 30° to examine the effect of the angle at which the examiner read the torque value (Figure 4). The average of the five measured torque values (average measured torque value) was calculated and recorded. The bias, which was the difference between the average measured and target torque values divided by the target torque value, was used as an index of accuracy. The coefficient of variation, which was the standard deviation of the measured torque value divided by the average measured torque value, was used as an index of repeatability.

Additionally, we clarified whether the influence of the part of the beam to be adjusted to the scale and the influence of the angle at which the examiner read the torque value were related to the structure of the torque wrench. Thus, the torque value per mm of the scale, the width of the scale line, the width of the beam, and the distance between the scale and the center of the beam were measured and compared with the bias and coefficient of variation.

As a statistical method, a paired t-test was performed with Bonferroni correction. In terms of accuracy, depending on the part of the beam, the calculated bias of the lower edge, center, and upper edge of the beam was used as the dependent variable. In terms of repeatability by beam site, the coefficient of variation of the lower edge, center, and upper edge of the beam was used as the dependent variable. In terms of accuracy depending on the angle at which the examiner reads the torque value, deviations of 90°, 60°, and 30° were used as dependent variables. In terms of repeatability depending on the angle at which the examiner read the torque value, deviations of 90°, 60°, and 30° were used as dependent variables. The significance level was set at 5%. Additionally, the four items of difference in torque value between the lower edge and upper edge, coefficient of variation in the center, the difference in torque value between 90° and 60°, and coefficient of variation when viewed from 60° were set as the dependent variables. Pearson's correlation coefficient was calculated between the dependent variable and the following four items: torque value per mm of scale, beamwidth, scale line width, and distance between scale and beam center. The significance level was set at 5% (Tables 2, 3, 4, 5).

IBM SPSS Statistics 25.0 (IBM, Chicago, USA) was used for statistical processing.

Results

3.1 Comparison of accuracy and repeatability depending on the part of the beam to be aligned

The bias and coefficient of variation, which are indicators of the accuracy of various torque wrenches, were used for comparison (Figure 5). In the torque wrench used in this study, as the part of the beam to be adjusted to the scale moves from the lower edge to the upper edge, the exerted torque value tended to increase (difference in maximum average measured torque value: ±9 N cm). There was a significant difference in bias between the groups, and the coefficient of variation was not significantly different between the groups ($P>0.05$). The highest accuracy and repeatability (bias within ±4%) when the center of the beam to be aligned was in the center of the scale among the five manufacturers. The difference in bias between the lower and upper edges of the same manufacturer varied greatly, from 12% for the smallest difference to 88% for the largest difference, depending on the manufacturer.

Manufacturers with a greater difference in bias between the lower and upper edges demonstrated an increase in the values of torque per mm of scale, the width of the beam, and the width of the scale line. The correlation coefficient between the difference in torque value between the lower and upper edges and each item was as follows; the torque value per 1 mm of the scale was 0.94, the beam width was 0.57, and the scale line width was 0.72 (Table 2). Additionally, we observed a tendency for the values of torque per mm of scale, beamwidth, and scale line width to increase for manufacturers with a higher coefficient of variation in the center. The correlation coefficients between the central coefficient of variation and each item were as follows; the torque value per mm of the scale was 0.47, the width of the beam was 0.29, and the width of the scale line was 0.83 (Table 3).

3.2 comparison of accuracy and repeatability by the angle from which the examiner reads the torque value

The bias and coefficient of variation, which are indices of the accuracy of various torque wrenches, were used to compare the demonstrated torque values of the seven manufacturers. The bias was significantly different only between the 90° and 60° groups, and the coefficient of variation was significantly different between the 90° and 30° groups and between the 60° and 30° groups ($P<0.05$). Five manufacturers demonstrated the highest accuracy (within ±7% bias) when the angle of torque reading was 90°, and seven manufacturers showed the highest repeatability (within 2% coefficient of variation) when the angle of torque reading was 90° (Figure 6).

The difference in the bias between 90° and 60° differed greatly among the manufacturers, ranging from 2% of the smallest difference to 33% of the largest difference. The correlation coefficients between the difference in torque values between the 90° and 60° scales and each item were as follows; per mm of torque value was 0.45, the distance between the scale and the center of the beam was 0.90, and the width of the scale line was 0.41 (Table 4). Manufacturers with a larger coefficient of variation, when viewed from 60°, tended to increase the torque value per mm scale, the distance between the scale and the center of the beam, and the width of the scale line. The coefficient of variation when viewed from 60° and the correlation coefficient of each item were as follows; the torque value per mm of the scale was 0.76; the distance between the scale and the center of the beam was 0.57, and the width of the scale line was 0.82 (Table 5).

Discussion

4.1 Research Methodology

4.1.1 Choosing a torque wrench

Although many torque wrenches exist, we considered it more clinically relevant to clarify the characteristics of those clinically used. Thus, in this study, we selected eight types of torque wrenches that are often used clinically in implant treatment, taking into consideration the market share.

4.1.2 The measurement of the torque value

For measuring the torque value of the torque wrenches, the Tohnichi torque gauge was used, managed, and calibrated by the torque management system according to the ISO 9001 standards with high utility. The calibrated values were as follows; (target value: 10 N cm, measured value: 10 N cm, 9.9 N cm); (target value: 30 N cm, measured value: 30 N cm, 29.7 N cm); (target value: 40 N cm, measured value: 40 N cm, 39.6 Ncm); (target value: 50 Ncm, measured value: 50 N cm, 49.7 N cm); (target value: 60 N cm, measured value: 59.8 N cm, 60 N cm). These values were within the measurement error range of 0% to 0.9%. The torque wrench used in this study demonstrated a maximum value of 89.4% and a minimum value of -40.6% for the lower edge of the beam. Thus, the accuracy of the torque measured by our method is considered to be high.

4.2. The effect of the part of the beam to be aligned to the scale

The location of the beam to be aligned was significantly more accurate at the center. No significant difference was observed; however, the reproducibility was highest at the center for many manufacturers. It was suggested that the scale should be set to the center of the scale when handling torque wrenches. Additionally, there were torque wrenches that were greatly affected by the part of the beam that was adjusted to the scale and torque wrenches that were less affected. Thus, the part of the beam to be adjusted to the scale and the structure of the torque wrench may be related. The structure of the torque wrenches was measured and discussed for clarifying the relationship between the structure of the torque wrenches and part of the beam to be aligned with the scales. In one of the torque wrenches used in this study, the distance between the 35 N cm-scale and the 15 N cm-scale was 5.5 mm, resulting in a torque value of 3.6 N cm per mm. Since the width of the beam was 1 mm, the theoretical value of the error at the upper and lower edges of the beam could be calculated. It was suggested that the width of the beam, which is the structure of the torque wrench, is related to the influence of the part of the beam that is adjusted to the scale (Figure 7). The correlation coefficients suggested that the torque value per 1 mm of the scale and the width of the scale line significantly affected the accuracy, and the width of the line significantly affected the repeatability. Based on the above, the present study indicates that it is desirable to adjust the scale to the center of the beam and consider the influence of the torque value per mm of the scale of the torque wrench and the width of the beam for each manufacturer.

4.3. The angle at which the examiner reads the torque value

The angle at which the examiner read the torque value was significantly more accurate at 90° than at 60° and was significantly more reproducible at 90° than at 30°. The accuracy and repeatability were both highest at the 90° reading angle for most manufacturers. Thus, it was suggested that the torque wrench should be read and used at 90°. Additionally, there were torque wrenches that were greatly affected by the angle at which the examiner read the torque value and torque wrenches that were less affected. Thus, it was suggested that the effect of the angle at which the examiner reads the torque value might be related to the structure of the torque wrench. The structure of the torque wrenches was measured and discussed to clarify the relationship between the structure of the torque wrenches and the angle at which the examiner read the torque value. In one of the torque wrenches used in this study, the distance between the scale and the center of the beam was 2 mm, and the distance between the point where the scale was read from 60° and the actual point perpendicular to the center of the beam was 1.15 mm. The torque value per mm was 3.6 N cm, as previously mentioned. The theoretical value of the error can be calculated by multiplying the distance between the point where the scale is read from 60° and the point on the vertical of the center of the beam. Thus, it was suggested that the distance between the center of the scale and the center of the beam was a factor affecting the angle (Figure 8). The correlation coefficients suggested that the distance between the scale and the center of the beam significantly affected the accuracy, and the torque value per mm of the scale and the width of the scale line significantly affected the repeatability. Therefore, the present study indicates that it is desirable to adjust the scale to the center of the beam and consider the influence of the torque wrench after considering the effects of the distance between the scale and the center of the beam, the width of the scale line, and the torque value per mm of the scale of the torque wrench for each manufacturer.

Limitations Of This Study And Future Perspectives

A limitation of this study is that the measurement of the torque wrench was done by a single examiner; therefore, inter-examiner measurement error was not considered. Additionally, a single torque wrench from each manufacturer was used for measurement. Thus, individual differences were not anticipated. This should be considered in future studies.

In the clinical environment, the accuracy and repeatability of torque wrenches change owing to metal fatigue, aging deterioration due to sterilization and cleaning, and wet conditions in the oral cavity. Based on the results of this study, the effect of aging on the accuracy and repeatability of torque wrenches and the prognostic effect of errors in tightening torque values must be clarified through future studies.

Conclusion

It was suggested that reading the torque wrench from 90° with the center of the beam aligned to the scale. The accuracy and repeatability differed among wrenches from different manufacturers. This was related to the torque value per mm of scale, the width of the scale line, the width of the beam, and the distance between the scale and the center of the beam. Thus, a torque wrench must be selected after understanding the differences in the structure, depending on the manufacturer.

Declarations

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

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Tables

Due to technical limitations, table 1-5 is only available as a download in the Supplemental Files section.

Figures

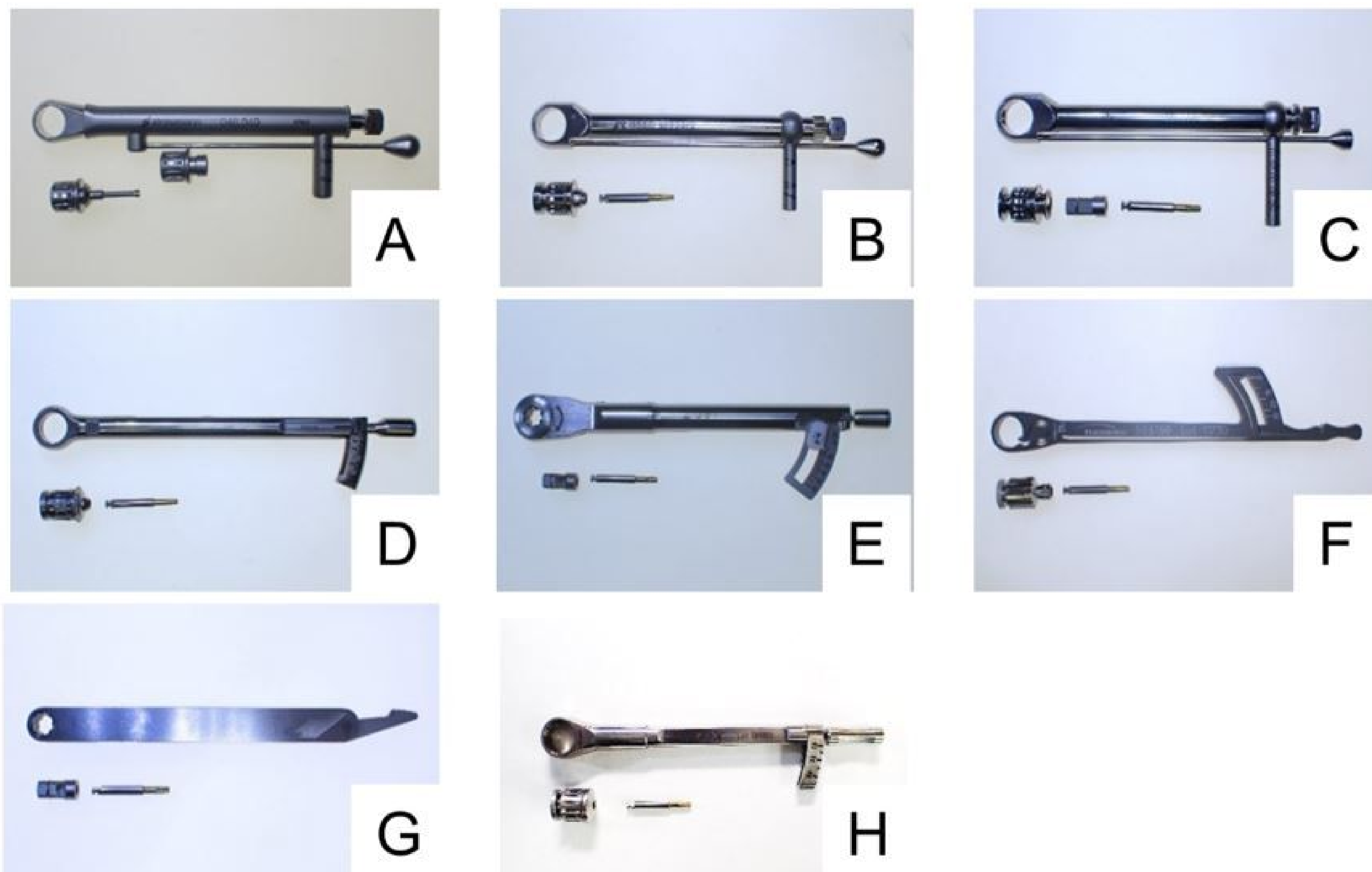

Figure 1

Type of torque wrench selected A Ratchet, Institute Straumann Ag, Basel, Switzerland, B: Manual Torque Wrench Prosthetic, Nobel Biocare, Zürich-Frughafen Switzerland, C: Ex Torque Wrench, Kyocera Medical Corporation, Osaka, Japan D: GC Implant Re and Surgical Instrument Torque Wrench, Gc, Tokyo, Japan

E: Torque Ratchet Wrench, Ktc, Kyoto, Japan，F: Mono torque ratchet, Thommen, Grenchen, Switzerland, G: Torque wrench, Nippon Piston Ring Co, Saitama, Japan H: Biofix Torque wrench, Shofu, Kyoto, Japan

Figure 2

Torque wrench and torque gauge fixed

Figure 3

Location of beam placed on scale A: lower edge，B: center，C: upper edge

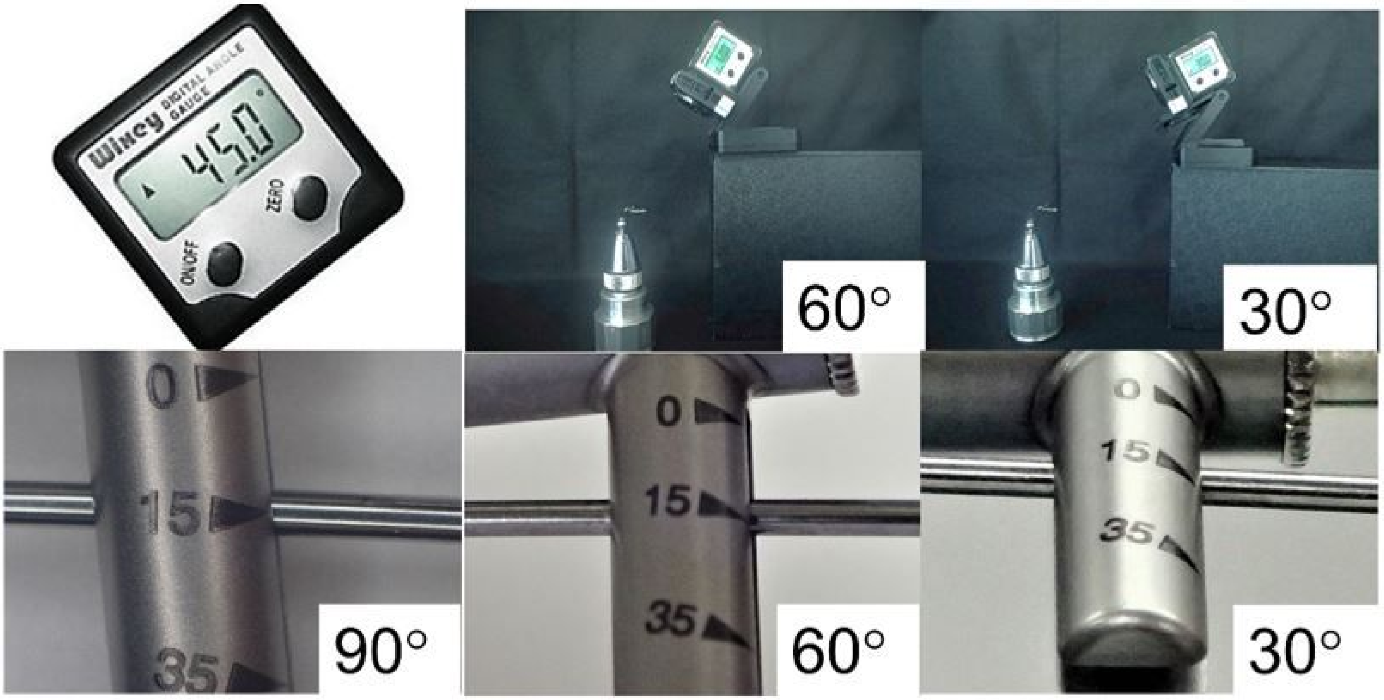

Figure 4

Angle at which the examiner reads the torque value

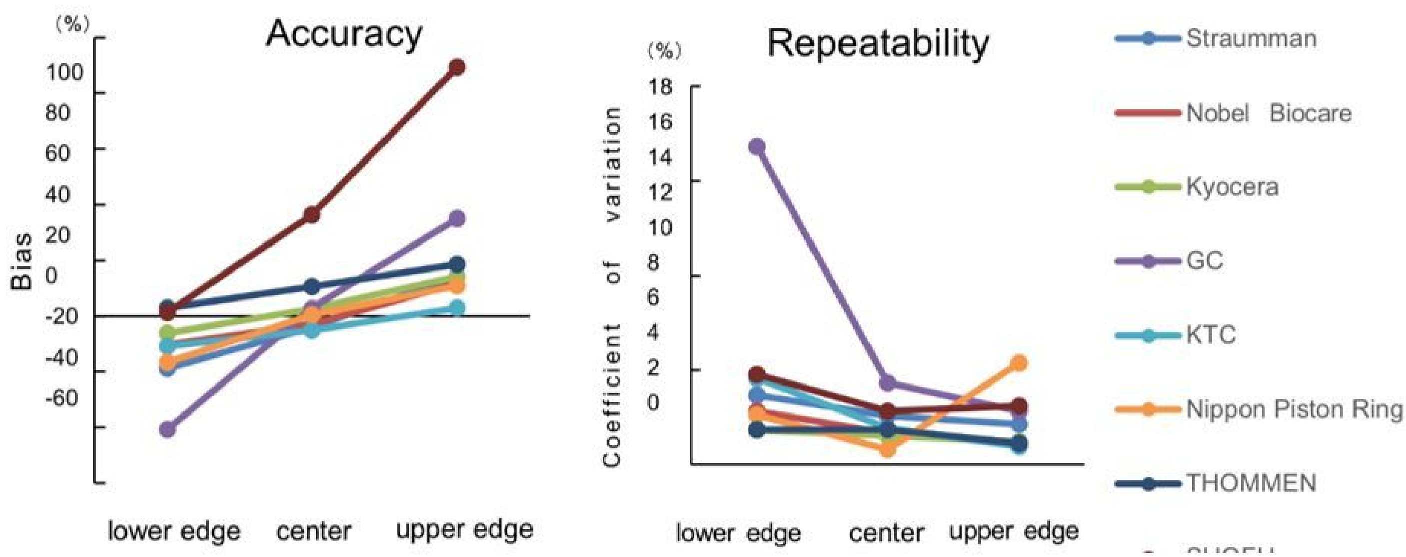

Figure 5

Comparison of accuracy and repeatability depending on the part of the beam to be scaled

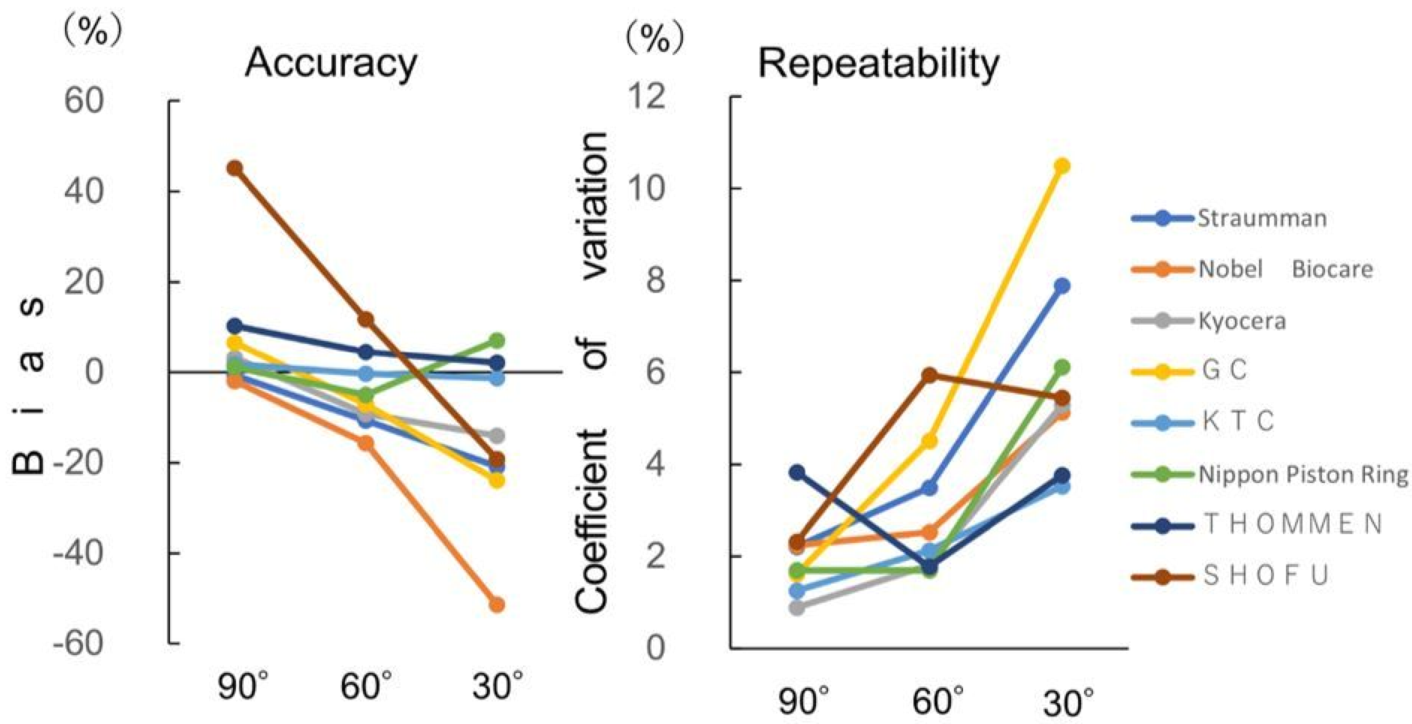

Figure 6

Comparison of accuracy and repeatability by the angle at which the examiner reads the torque value

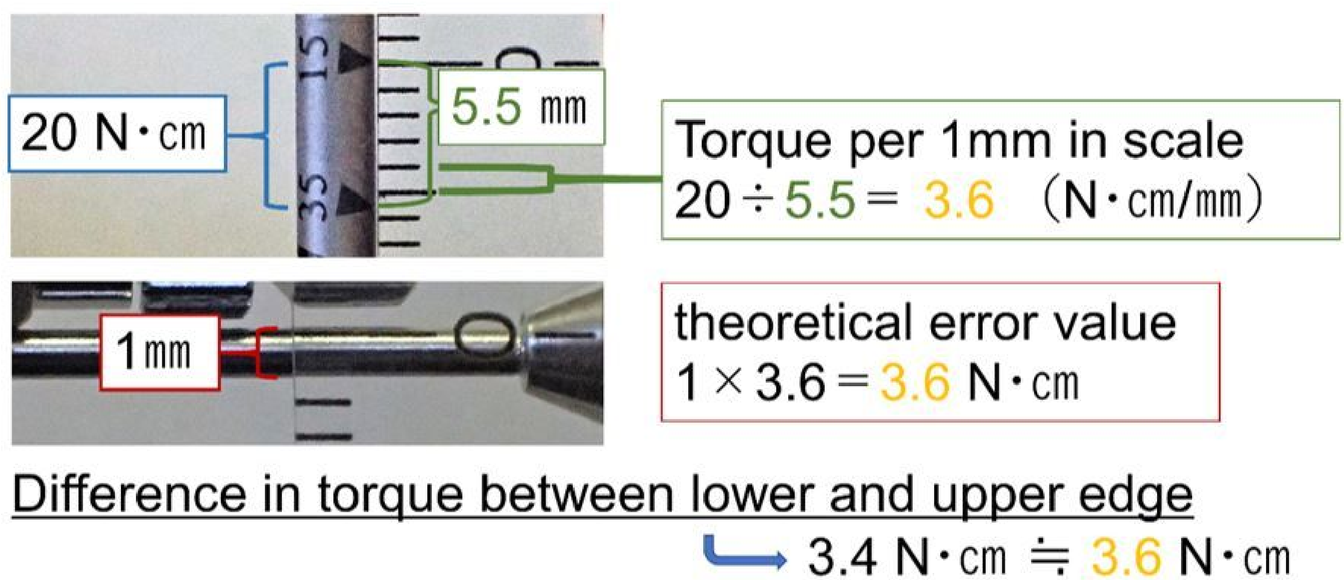

Figure 7

Consideration of the effect of the beam part to be adjusted to the scale

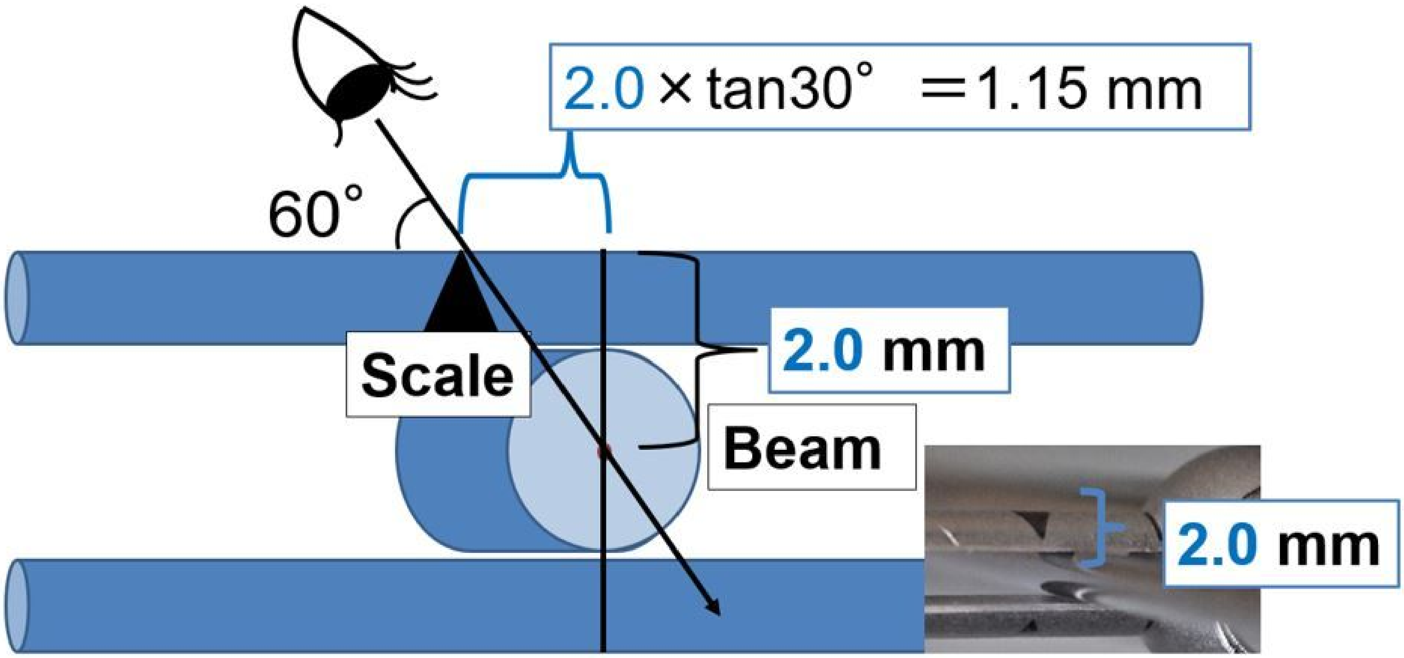

Figure 8

Consideration of the effect of the angle at which the examiner reads the torque value

Supplementary Files

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