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RESEARCH AND EDUCATION

Comparison of the torque transferred to the implant-bone interface when tightening abutment screws and when torque testing implants: An in vitro study

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ABSTRACT

Statement of problem. Before dental implants are restored, osseointegration is often verified by torque testing the implant. For this test, it might be appropriate to select the torque subsequently used to tighten the abutment screw during prosthetic delivery. However, whether the full torque applied to the abutment screw is transferred to the implant-bone interface remains unknown.

Purpose. The purpose of this in vitro study was to assess whether the same torque is transferred to the implant-bone interface when tightening abutment screws and when torque testing implants and to investigate whether the implant system used affects the torque transfer.

Material and methods. A digital torque gauge was used to register the torque directed to a simulated implant-bone interface. Twenty implants from 4 different manufacturers were successively secured to the digital torque gauge. An implant driver was used to torque test the implant. An implant abutment screw was then tightened to attach a universal base (TiBase) abutment to the implant. During both tests, a mechanical torque limiting device was used to apply the same manufacturer-specific torque. For both experiments, the peak torque transferred to the simulated implant-bone interface was recorded. To allow pooling data from different torque targets, the data were converted into absolute difference. A *t* test was used to evaluate whether the same magnitude of torque was transferred to the implant-bone interface when tightening abutment screws and when torque testing implants. An ANOVA was used to test whether the percentage of torque transferred to the implant-bone interface was impacted by the implant system used (α=.05).

Results. No significant difference was found between the torque transmitted when tightening an abutment screw and that transmitted when torque testing the implant (*P*=.600). Also, no difference was found in the percentage of torque transferred to the simulated implant-bone interface of different implant systems (*P*=.996).

Conclusions. Regardless of the implant system used, when tightening abutment screws and when torque testing implants, the same amount of torque is transferred to the implant-bone interface. (J Prosthet Dent 2021;■:■-■)

The most common method of fixation between an endosseous implant and an implant-retained prosthesis is the screw joint, created when a screw is used to connect 2 parts.[1] When the abutment screw is tightened, the rotational force creates a tensile force within the screw known as preload. As the preload is increased, the screw stretches, and its elastic recovery creates a compressive force, the clamping force, that secures the screw joint.[1-4]

Screw loosening during function is one of the most common complications associated with implant-supported prostheses.[2,5-7] Off-axis occlusal loading creates joint separating forces in the screw joint.[1] The screw will only loosen if external forces are sufficient to cause the screw joint to open and close multi-

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Clinical Implications

When tightening abutment screws, full torque is transferred to the implant-bone interface. As such, clinicians should ensure the implant-bone junction can withstand this torque before installing implant-retained restorations. Manufacturer recommendations for torque when tightening abutment screws should also be selected when torque testing implants.

ple times.[1,2] For that to happen, the external forces separating the parts of the joint must be greater than the force keeping them together. Therefore, to avoid screw loosening, the joint clamping force must be maximized, and the joint separating forces minimized.[1,2] However, if excessive preload is applied to the screw, it risks fracturing.[4] To reduce that risk, the torque applied to a screw should be limited to 75% of the torque, resulting in its distortion or fracture.[1,3,8,9] Implant manufacturers generally recommend a certain abutment screw tightening value specific to their system.[10]

Before attaching prostheses to dental implants, successful osseointegration must be verified, partly to ensure that the implant-bone interface has sufficient strength to withstand the rotational force absorbed when applying the prescribed preload to the screw joint. Different techniques have been used to evaluate osseointegration,[11,12] with the reverse torque test being commonly used.[11] Torque testing implants from all manufacturers at the same arbitrary magnitudes ranging from 20 to 35 Ncm has been suggested.[13-15] However, it might be more appropriate to torque test implants at a level equivalent to what is subsequently used to tighten the abutment screw during prosthetic delivery if the entirety of the torque exerted on the abutment screw is transferred to the implant-bone interface. However, the authors are unaware of studies that measured the actual amount of torque transmitted to the implant-bone interface when tightening an abutment screw. Nevertheless, only a fraction of the torque applied to the screw joint is used to form the preload.[16,17] Most of the torque applied to the abutment screw is lost to friction, heat, screw deformation, and elongation.[17,18] The ratio of force converted into preload varies depending on the characteristics of the screw joint and whether a lubricant is used.[16,17] It is possible that only a portion of the torque applied to an abutment screw is transferred to the implant-bone interface. If this assumption is true, a lower torque may be required when reverse torque testing implants than when tightening abutment screws. This could result in a reduced failure rate for reverse torque tests.[19]

The main objective of this study was, therefore, to evaluate whether there is a difference in the amount of torque transferred to the implant-bone junction when torque testing an implant and when an abutment screw is tightened according to the manufacturer's recommendations. The secondary objective was to test whether this relation varies for different types of implants. The null hypotheses were that no difference would be found between the torque transferred to the implant-bone junction when tightening abutment screws and when torque testing implants and that the type of implant would not influence the transfer of force.

MATERIAL AND METHODS

Dental implants from 4 manufacturers with similar diameters and lengths were investigated (Table 1). Because the authors were unaware of similar studies, a power analysis could not be performed to determine the sample size. Therefore, a sample size of 20 implants (5 per manufacturer) was selected arbitrarily. For each implant system, 5 implants, 5 genuine universal base (TiBase) abutments, and 5 genuine abutment screws were purchased (Table 1). A digital torque gauge (TT03-12; MARK-10 Corp) was used to measure the torque transferred to the simulated implant-bone interface, and a precision vise (STHT83179 Quick Vise; Stanley Black & Decker Inc) was used to secure the digital torque gauge to a table (Fig. 1).

To limit the use of different mechanical torque limiting devices (MTLDs) and therefore reduce the risk of calibration issues, a new spring-style MTLD (Astra Tech EV; Dentsply Sirona) was used to apply torque to all implants and abutment screws from Nobel Biocare, Astra Tech, and Biomet 3i. This MTLD is calibrated for all torque targets used with these implant systems (Table 2). However, because Straumann screw drivers are not compatible with torque wrenches from other manufacturers, a Straumann spring-style MTLD was also used. Calibration tests were performed by using an additional implant to confirm that both the operator and the MTLDs were calibrated and reliable. Manufacturer-specific short implant drivers were used to engage the implants and simulate torque testing, and manufacturer-specific short screwdriver tips were used to tighten abutment screws (Table 1).

To perform the measurements, the dental implants were secured to the 3-jaw chuck on the digital torque gauge. A simulated torque test was performed first, a universal base abutment and screw were placed on the implant (Fig. 2), and the same torque was applied to the abutment screw (Fig. 3). For both tests, the torque was applied slowly until it reached the abutment screw tightening torque recommended by the manufacturer

Table 1. Implants, abutments, and screwdrivers included

Implant System −Diameter×Length (mm)	Abutment Collar Height (mm)	Screwdriver Tip (mm)
Nobel Biocare Active−4.3×11.5	Universal Base (1.5)	Unigrip (25)
Astra Tech OsseoSpeed EV −4.2×11	TitaniumBase (2)	Hex Driver (24)
Biomet 3i Certain Prevail −4.1×11.5	FlexLink TiBase (0.5)	Hexed Driver (24)
Straumann CrossFit Roxolid −4.1×12	Variobase (1)	SCS (21)

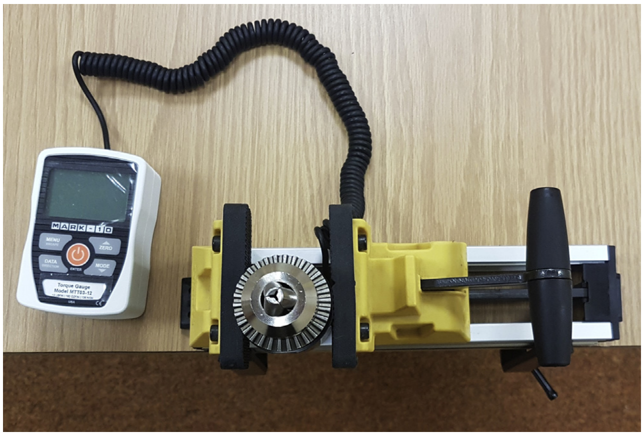

Figure 1. Digital torque gauge secured to table by using precision vise.

Table 2. Mean values for data obtained

Implant System	Target (Ncm)	Abutment Screw ±SD (Ncm)	AD Abutment Screw ±SD (Ncm)	Torque Test ±SD (Ncm)	AD Torque Test ±SD (Ncm)	Percentage of Transfer ±SD (%)
Nobel	35	35.18 ±1.24	0.98 ±0.62	36.44 ±0.53	1.44 ±0.53	96.54 ±3.41
Astra Tech	25	25.66 ±0.98	0.94 ±0.63	26.68 ±0.51	1.68 ±0.51	96.18 ±3.66
Biomet 3i	20	20.26 ±0.55	0.50 ±0.26	20.96 ±0.69	1.04 ±0.52	96.66 ±2.60
Straumann	35	33.30 ±0.80	1.70 ±0.80	34.58 ±0.69	0.50 ±0.62	96.30 ±2.31

SD, standard deviation.

(Table 2). The peak torque values, in Ncm, measured with the digital gauge were recorded as “torque test” and “abutment screw.” The operator (F.Y.F.) was blind to the readings, and the peak torque value was read by an assistant (E.K.). The tests were repeated in random order for each of the 20 implants, each time with new components. To achieve randomization, each of the 20 implants was assigned a number from 1 to 20 drawn from an opaque bag.

Because the 4 manufacturers recommend 3 different torque targets (Table 2), the raw data could not be compared directly. Therefore, data from both tests were transformed into the absolute difference (AD) between the value measured and the torque targeted by the operator by using the equation AD=| peak torque measured−target torque |.[20,21] Using the AD, a paired samples *t* test was performed to analyze whether the torque transferred to the implant-bone interface was similar when torque testing implants and when tightening abutment screws at the same torque target. A 1-way ANOVA was used to test whether the implant systems influenced the percentage of the torque transferred to the implant-bone junction when tightening an abutment screw. To conduct that test, data were converted into percentage values by using the formula % =(abutment screw/torque test)×100, where the peak torque measured when tightening abutment screws and the peak torque measured when torque testing implants were used. Statistical analyses were performed by using a statistical software program (IBM SPSS Statistics, v26; IBM Corp) (α=.05). Normal distribution of data and homogeneity of variance were confirmed by using the Shapiro-Wilk test (P>.05) and the Levine test (P>.05).

RESULTS

All data obtained are presented in Table 2. As determined by a paired samples *t* test (t(19)=0.533, P=.600), no difference was observed between the absolute difference of torque transferred to the implant-bone junction when tightening abutment screws (mean ±standard deviation AD: 1.03 ±0.71 Ncm) or when torque testing implants (mean ±standard deviation AD: 1.17 ±0.68 Ncm). For all implant systems, when tightening abutment screws, the percentage of torque transmitted to the simulated bone-implant junction was between 96% and 97%, and the difference was not statistically significant (F(3,16)=0.019, P=.996).

DISCUSSION

The purpose of this study was to evaluate whether there is a difference between the torque transferred to the implant-bone junction when torque testing implants and that when tightening abutment screws to the manufacturer’s recommended torque for abutment screws. The secondary objective was to evaluate whether the ratio of torque transferred to the implant-bone junction was influenced by the implant systems. The results showed that torque testing and tightening abutment screws transferred the same magnitude of torque to the implant-

Figure 2. Implant and universal base abutment secured in 3-jaw chuck of digital torque gauge.

bone interface. The relationship observed was similar for all implant systems tested. The results from this study, therefore, suggest that to evaluate osseointegration, torque testing implants should be performed with the same force subsequently used to tighten the abutment screws. This value will ensure that the bone-implant junction will be strong enough to withstand the torque transferred when tightening the abutment screw.

These findings are important because, although it has been suggested that reverse torque testing be performed at the manufacturer's recommended torque for the insertion of the abutment screw, the authors are unaware of a previous study that showed that these procedures produce the same torque at the implant-bone interface. While it was assumed that the peak torque put on an abutment screw is fully transferred to the implant-bone interface, most of the torque applied to the abutment screw is lost to friction, heat, screw deformation, and elongation.[17,18] To avoid unnecessary biological and mechanical stresses, if torque less than the full torque used to tighten abutment screws were transferred to the

Figure 3. Mechanical torque limiting device used to tighten abutment screw while second operator read torque applied.

implant-bone interface, less force should also be used to torque test implants.[19]

In the in vitro study, a digital torque gauge was used to measure the peak torque values produced on a simulated implant-bone interface when torque testing implants and when tightening abutment screws. There was no assumption that the force created during torque testing was fully transferred to the implant-bone interface. Instead, it was measured as part of the study design. Therefore, instead of comparing the torque transferred to the simulated implant-bone junction when tightening an abutment screw to the torque being targeted, it was compared with the torque observed when torque testing the implant at the same torque target. This protocol ensured that the measurement inaccuracies from the MTLDs, the digital torque gauge, and the operator were similar for both variables compared.

Because data were measured at target torque values of 20, 25, and 35 Ncm, direct pooling of raw data for statistical analyses could not be performed. Instead, the difference between the peak torque measured and the torque target was calculated for each measurement. These differences were then converted into absolute values to allow for calculating the mean without positive values above the target torque canceling the negative values under the target torque. The mean absolute differences observed for both variables are presented in Table 2. Absolute difference (AD) was described, as used in previous studies.[20,21] To generalize the main findings, an analysis was designed to evaluate whether the percentage of torque transferred to the implant-bone interface when tightening an abutment screw was influenced by the implant brand. As detailed, to mitigate potential measurement imprecisions, the percentage of transfer was calculated by using the values measured when tightening abutment screws and when torque testing. The 4 implant systems included in this study had different implant, abutment, and screw morphology, materials, and torque targets. The finding that no statistically significant difference was observed between the implant systems suggests that the results are generalizable to different implant systems.

Limitations of the study included that only a limited sample of implant systems were investigated and no implants with external connections were included. Other materials and screw designs may behave differently. Inaccuracies from the operator or the MTLDs could have affected the results, but this was mitigated by calibrating the operator and MTLDs before testing. A chuck-implant interface was used to simulate the implant-bone interface. Although this simulation is different than the implant-bone interface, it nonetheless provides a realistic model because implants are anchored in direct contact with bone when successfully osseointegrated.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. When tightening abutment screws and when torque testing implants, the same amount of torque is transferred to the implant-bone interface.
2. This relationship is independent of the implant system used.
3. The torque magnitude recommended by the manufacturer to tighten abutment screws should also be selected when osseointegration is confirmed with a reverse torque test.

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