The Overuse of the Implant Motor: Effect on the Output Torque in Overloading Condition

Du-Hyeong Lee, DDS, MS;* Sung-Am Cho, DDS, PhD;† Cheong-Hee Lee, DDS, PhD;†
Kyu-Bok Lee, DDS, PhD‡

ABSTRACT

Background: The overloading of the motor affects its performance. The output torque of the implant motor under overloading condition has not been reported.

Purpose: The purpose of this study was to determine the reliability and the tendency of the output torque when an implant motor is consecutively used.

Materials and Methods: Three implant motors were evaluated: SurgicXT/X-SG20L (NSK), INTRAsurg300/CL3–09 (KaVo), and XIP10/CRB26LX (Saeshin). The output torque was measured using an electronic torque gauge fixed with jigs. For the 40 and 50 Ncm torque settings, 300 measurements were taken at 30 rpm. Repeated measures of analysis of variance (ANOVA) and one-way ANOVA were used to compare the torque values within each group and between the groups.

Results: As repeating measures, the output torque values decreased gradually compared with the baseline. In within-group analysis, the different torque value from the first measurement appeared earliest in NSK motor, followed in order by Saeshin and KaVo motors. NSK motor showed a different torque decrease between 40 and 50 Ncm settings ($p < .05$). Intergroup analysis revealed Saeshin motor to have the least deviation from the baseline, followed by KaVo motor. NSK motor had the most inconsistent torque at the 6, 8, 9, and 10 repeat counts ($p < .05$).

Conclusion: The actual torque decreases when the surgical motor is continuously used. The NSK motor showed more significant decreases in torque than KaVo and Saeshin motors in overloading condition.

KEY WORDS: implant motor, output torque, overloading, overuse, torque decrease

INTRODUCTION

The electric handpiece has several differences over the conventional air turbine.[1–4] The micromotor of the electric handpiece generates higher torque at a constant running speed. The high torque provides clinicians with improved tactile feedback, which enables more controlled treatment. The greater cutting efficiency and lack of stalling are other advantages of the electric handpiece.

The implant treatment includes the procedures of fixture placement and the fixation of fastening prosthetic screws.[5] These steps require high torque in ultralow rotational speeds. The electric handpiece has been used as the standard instrument in implant surgery because its features satisfy the requirements of implant treatments.

Roberts and colleagues evaluated the clinical usage time of handpieces in oral surgical procedures through a comparison with the manufacturer's recommendations.[6] As the handpiece run time increased with the complexity of the surgical case, 94 of the 100 cases violated the 20/50 rule (handpiece usage for less than 20 seconds for every 50 seconds).[7] The overuse of a handpiece generates heat not only in bone tissue but also in the motor of the handpiece. Frictional heat from bone drilling can cause thermal necrosis of bone.[8,9] Eriksson

*Assistant professor, Department of Prosthodontics, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea; †professor, Department of Prosthodontics, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea; ‡associate professor, Department of Prosthodontics, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea

Corresponding Author: Prof. Kyu-Bok Lee, Department of Prosthodontics, College of Dentistry, Kyungpook National University, 2177 Dalgubeoldae-ro, Jung-gu, Daegu, 700-412, South Korea; e-mail: kblee@knu.ac.kr

This article was published online on January 3, 2014. An error in the author list was subsequently identified. This notice is included in the online and print versions to indicate that both have been corrected February 10, 2014.

DOI 10.1111/cid.12195

and Adell suggested that bone temperature should be below 47°C during drilling.[10] The heat on a handpiece is brought about by its elements such as the stator, rotor, and bearing system.[11] The heat affects the motor efficiency as well as the useful life of the device. The overheated components can lead to poorer motor performance. Christensen also indicated that heat causes considerable degeneration of the moving parts of handpieces.[12]

Some studies reported the accuracy of the applied torque and its reliability in surgical motors by measuring the output torque.[13,14] They concluded that surgical motors exhibit variations in torque output. On the other hand, the consistency of output torques has not been reported when repeating the measures. It is conceivable that the output torque can be different when the surgical motor is overloaded. This hypothesis was tested in this study by measuring the output torque of surgical motors in 40 and 50 Ncm settings over 10 repeat counts.

MATERIALS AND METHODS

Three brands of surgical implant engines were selected: SurgicXT/X-SG20L (NSK, Kanuma, Japan), INTRAsurg300/CL3–09 (KaVo, Biberach, Germany), and XIP10/CRB26LX (Saeshin, Daegu, South Korea). Table 1 lists the technical capacities of the controllers and handpieces. All equipment varied in the range of the gear ratio, revolutions per minute (rpm), and generating torque. The following shows the data provided by the manufacturer.

NSK SurgicXT has an auto-calibration facility that recognizes the resistance of each handpiece attached to the motor to obtain the precise rpm and torque. The gear ratio can be switched from 1:5 increasing to 256:1 reducing. X-SG20L is equipped with a gear with a 20:1 reduction ratio and a 50 Ncm maximum torque. The operating speed ranges from 10 to 2,000 rpm when mounted on the SurgicXT. KaVo INTRAsurg300 provides a speed ranging from 300 to 12,000 rpm with a maximum torque of 5.5 Ncm. The speed limit function controls the rpm and torque to protect the motor and bone. A built-in gear ratio is 27:1. This controller does not have another option for the torque. CL3–09 is comprised of the head CL3 and shank CL09. The total gear ratio is 27:1, which is composed of 3:1 of CL3 and 9:1 of CL09. The largest operating speed is 1,500 rpm with a 55 Ncm maximum torque. Saeshin XIP10 offers gear ratios ranging from 1:5 increasing to 64:1 reducing. The controller is equipped with automatic overloading protection. This controller memorizes 10 program sets. CRB26LX adopts a 20:1 gear ratio, which generates a torque up to 55 Ncm.

The European Medical Device Directive permits controllers with closed brushless direct current motors to be used in surgical operating rooms. All devices have been tested and confirmed for use by the US Food and Drug Administration. The devices were new and operated according to the manufacturers' instructions.

Torque Measurement Procedure

The torque was tested using a MTT03–12 torque gauge (MARK-10 Corporation, New York, NY, USA) (Figure 1). The torque gauge was calibrated at the factory with an accuracy of ±0.5% of the full-scale ±1 digit, which can gauge the torque value to 135 Ncm. A chuck drill was inserted into the head of the handpiece. The other side of the drill was installed in a chuck of the torque gauge. The handpiece and torque gauge were fixed with jigs to obtain reliable outcomes. The head of the handpiece and torque gauge were aligned straight using the adjusting pin in the back side of the head to acquire a null adjustment with the x, y, and z axis.

TABLE 1 Technical Data for the Motors and Handpieces

Manufacturer	Device	Max rpm	Min rpm	Max Torque (Ncm)	Power (W)	Gear Ratio
NSK	SurgicXT	40,000	200	5	210	
	X-SG20L	2,000	10	50		20:1
KaVo	INTRAsurg300	40,000	300	5.5	100	
	CL3–09	1,500	11	55		27:1
Saeshin	XIP10	40,000	1,000	5	120	
	CRB26LX	2,000	30	55		20:1

rpm = revolutions per minute.

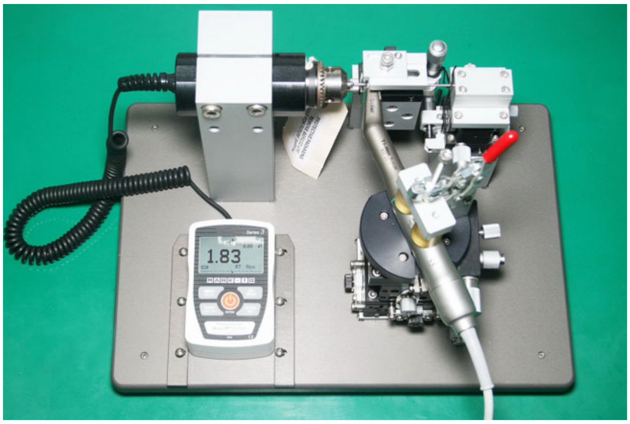

Figure 1 MTT03–12 torque gauge (Mark-10). The handpiece and torque gauge were fixed with jigs, aligning the head of the handpiece and torque gauge straight.

The speed of the surgical motor was set to 30 rpm. A no-load operation for 1 minute was given to settle the mechanical components before recording the torque. The preset torque levels were 40 and 50 Ncm. The controller was operated until the motors reached the set torques where the torque gauge beeped. Ten measurements were performed ceaselessly. Five sets of 10 measurements were carried out at each torque. A 5-minute break was given between sets to prevent unintentionally overloading the surgical motors. A total of 100 torque values were recorded for each motor. All torque measurements were carried out by a single investigator. The output values were recorded by two other researchers, who were blinded to the study aims.

Statistical Analysis

The first torque value was fixed as the baseline in each setting. The absolute deviations (Ncm) of the torque from the baseline were determined in the order of measurements using SPSS for Windows 18.0 (SPSS Inc., Chicago, IL, USA). The data are reported as the mean ± standard deviation and visualized via line graphs. Repeated measures of analysis of variance (ANOVA) were used to compare the torque values with the baseline within group and to verify the interaction between the torque level and the tendency of the output torques during the repetition of the measurement. One-way ANOVA with a Tukey HSD post hoc test was used to calculate the significant differences between the groups at a given repeat count. A p value < .05 was considered significant.

RESULTS

Set torque values of two levels, 40 and 50 Ncm, were used with a total of 300 measurements collected for statistical analysis.

The Tendency of the Output Torques within the Brand

The output torque values decreased gradually compared with the baseline as the measurement was repeated. In NSK SurgicXT/X-SG20L, the output values were significantly different from the baseline since the third measurement ($p < .05$). When KaVo INTRAsurg300/CL3–09 and Saeshin XIP10/CRB26LX were tested, the output values differed according to the baseline from the sixth and fifth measurement ($p < .05$).

The Interaction between the Torque Level and the Tendency of Output Torques

The NSK SurgicXT/X-SG20L showed different output torque distributions between 40 and 50 Ncm settings ($p < .05$; Figures 2 and 3). The output torque of 40 Ncm setting decreased by 1.533, whereas the outputs of the 50 Ncm setting decreased by 5.233. On the other hand, KaVo INTRAsurg300/CL3–09 and SaeshinXIP10/CRB26LX showed no differences in the progressions of the output torque between the 40 and 50 Ncm settings ($p > .05$).

The Comparison of the Torque Deviations between the Groups at a Given Repeat Count

In the 40 Ncm torque setting, NSK SurgicXT/X-SG20L was the closest to the baseline, followed by Saeshin XIP10/CRB26LX (Table 2, Figure 2). Although KaVo INTRAsurg300/CL3–09 exhibited the lowest output compared with the baseline, there was no significant difference from each other in all repeat counts ($p > .05$). When the 50 Ncm torque setting was tested, Saeshin XIP10/CRB26LX showed the lowest deviations from the baseline, followed by KaVo INTRAsurg300/CL3–09 (Table 3, Figure 3). No significant differences were observed in both groups. NSK SurgicXT/X-SG20L showed the most inconsistent torque among the groups. The analytical statistics showed that NSK SurgicXT/X-SG20L was different from the others at the 6, 8, 9, and 10 repeat counts ($p < .05$).

DISCUSSION

This study examined the consistency of the output torque and the effects of the input torque on the output

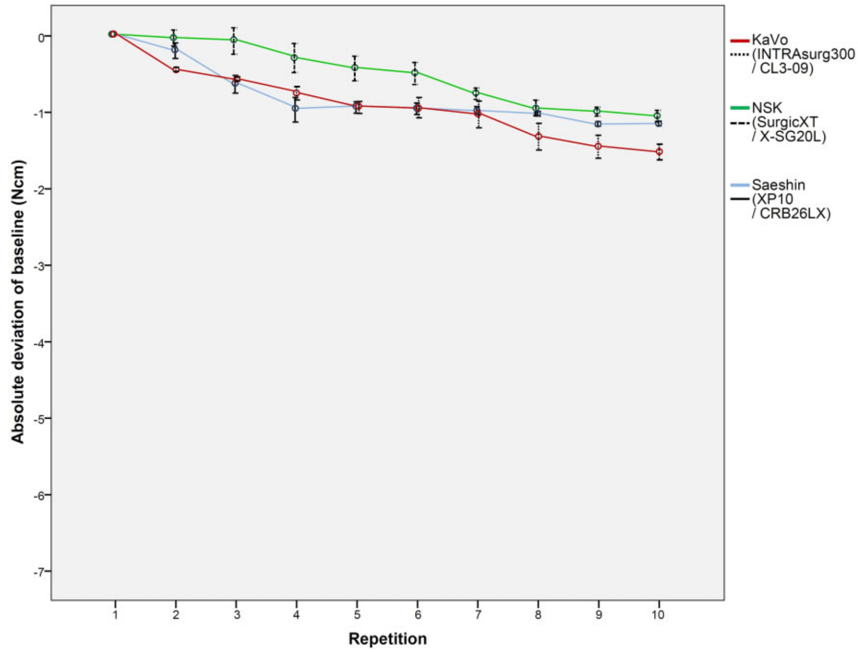

Figure 2 Absolute deviation of the torque value from the baseline for 40 Ncm setting.

torque under continuous operation. The most commonly used devices of NSK, KaVo, and Saeshin were included in the present experiment. The torque was measured using an electric torque gauge. The jigs were used to hold the handpiece and torque gauge firmly, enabling the head of the handpiece and chuck of the torque gauge to be straight. Neugebauer and colleagues used a different method to measure the torque. The hands were used to hold the handpiece and torque gauge to simulate the clinical situations.[13] On the other hand, the purpose of the present study was to determine the repeatability of the output torque, which is related

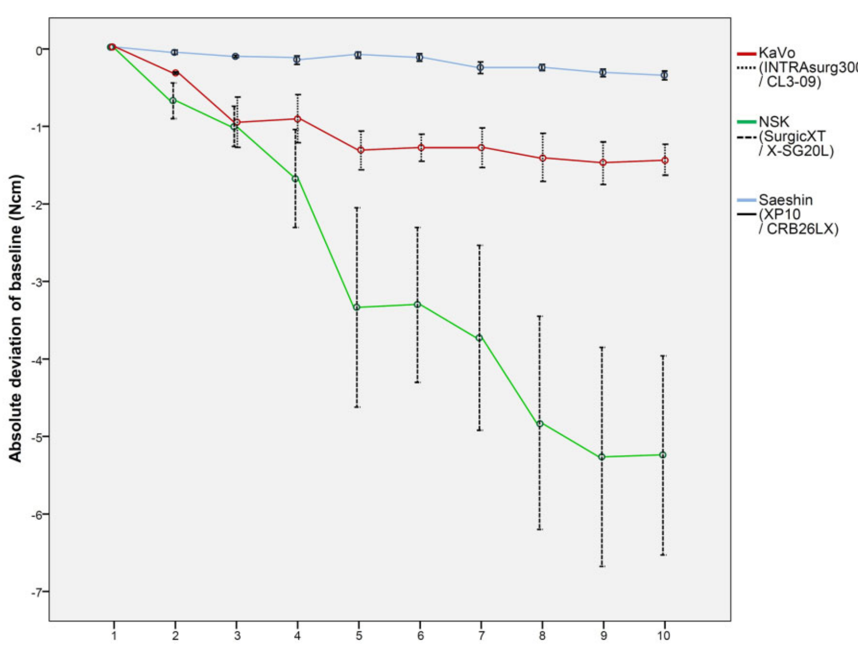

Figure 3 Absolute deviation of the torque value from the baseline for a 50 Ncm setting.

TABLE 2 Absolute Deviation of the Torque for 40 Ncm Setting (Mean ± SD)

Repetition	SurgicXT/X-SG20L	INTRAsurg300/CL3–09	XIP10/CRB26LX
1	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
2	−0.467 ± 0.208	−0.033 ± 0.058	−0.200 ± 0.200
3	−0.600 ± 0.346	−0.067 ± 0.058	−0.633 ± 0.231
4	−0.767 ± 0.379	−0.300 ± 0.173	−0.967 ± 0.321
5	−0.933 ± 0.321	−0.433 ± 0.153	−0.933 ± 0.153
6	−0.967 ± 0.289	−0.500 ± 0.265	−0.967 ± 0.153
7	−1.033 ± 0.153	−0.767 ± 0.351	−1.000 ± 0.100
8	−1.333 ± 0.208	−0.967 ± 0.351	−1.033 ± 0.058
9	−1.467 ± 0.115	−1.000 ± 0.300	−1.167 ± 0.058
10	−1.533 ± 0.153	−1.067 ± 0.208	−1.167 ± 0.058

SD = standard deviation.

to the intrinsic capacity of the devices. Accordingly, controlled metrics are essential for obtaining reliable data. Mechanical fixation eliminates the potential influence of the examiner by negating the need for use of the hands.

The output torque decreased gradually compared with the first torque value when repeating the measures. The phenomenon of torque sinking might be related to overloading of the motor.[11] The motor system has three elements: the stator, rotor, and bearing system. The motor cooling system is comprised of the frame, lamination, end turns, rotor end rings, fan, and other elements. The two systems must be harmonized sufficiently to remove the heat generated by the motor load through the motor cooling system. Consecutive operation of the handpiece generates heat in the moving parts. This heat reduces the motor performance, which definitely affects the torque. The effect of overloading accounts for the marked decrease in torque at 50 Ncm setting compared with the 40 Ncm setting.

NSK SurgicXT/X-SG20L showed significantly different values compared with the baseline from the third measurement. KaVo INTRAsurg300/CL3–09 and Saeshin XIP10/CRB26LX showed different values from the sixth and fifth measurement, respectively. This suggests that the torque consistency under extreme conditions of the NSK device might be inferior to the KaVo and Saeshin devices. Clinicians generally do not consecutively exert high torque during an implant surgery. Trisi and colleagues, however, compared a high torque group (mean 110 Ncm) with a low torque group (mean 10 Ncm) in terms of the histological and biomechanical

TABLE 3 Absolute Deviation of the Torque for 50 Ncm Setting (Mean ± SD)

Repetition	SurgicXT/X-SG20L	INTRAsurg300/CL3–09	XIP10/CRB26LX
1	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
2	−0.667 ± 0.462	−0.300 ± 0.000	−0.033 ± 0.058
3	−1.000 ± 0.520	−0.933 ± 0.666	−0.100 ± 0.000
4	−1.667 ± 1.266	−0.900 ± 0.624	−0.133 ± 0.115
5	−3.333 ± 2.574	−1.300 ± 0.500	−0.067 ± 0.058
6	−3.300 ± 1.997[*]	−1.267 ± 0.351[†]	−0.100 ± 0.100[†]
7	−3.733 ± 2.386	−1.267 ± 0.513	−0.233 ± 0.153
8	−4.833 ± 2.754[‡]	−1.400 ± 0.624[§]	−0.233 ± 0.058[§]
9	−5.267 ± 2.829[‖]	−1.467 ± 0.551[¶]	−0.300 ± 0.100[¶]
10	−5.233 ± 2.579[#]	−1.433 ± 0.404[**]	−0.333 ± 0.115[**]

The same superscripted symbols represent statistically similar groups (Tukey test).
SD = standard deviation.

phenomena at the bone-implant interface of the implants. They concluded that a high-implant insertion torque increased the primary stability of the implant.[15] Khayat and colleagues also showed that the use of a high-insertion torque did not prevent osseointegration between the bone and implant surface.[16] Therefore, some clinicians try to use a high-insertion torque. This often interrupts drilling due to friction between the surrounding bone and the fixture. The clinician might fail if he or she continues to run the handpiece restlessly to avoid being stuck. As the present findings showed, the actual output torque decreases when the surgical motor is used continuously. Accordingly, when a fixture is stuck in bone during surgery, it is recommended that clinicians use the implant torque wrench to obtain a high-insertion torque. Malfunction detection is important for guaranteeing the quality of the operation and protecting expensive equipments.[17]

To the best of the authors' knowledge, this study is the first to examine the interactions between the input torque and the consistency of the output torque. KaVo INTRAsurg300/CL3–09 and Saeshin XIP10/CRB26LX had a similar appearance of the measured torque at 40 and 50 Ncm, which means that the difference in torque power did not affect the tendency of the output torque. Interestingly, in SurgicXT/X-SG20L, the progression of the output torque was significantly different at the 40 and 50 Ncm settings. In particular, the reproducibility of the output torque can differ according to the torque level in some devices.

Between-group analysis showed that the three groups had a similar output torque in the repeat count of a 40 Ncm input torque. When a 50 Ncm torque setting was tested, Saeshin XIP10/CRB26LX and KaVo INTRAsurg300/CL3–09 had a different appearance of the output torque than NSK SurgicXT/X-SG20L. The values of the former were more consistent than those of the latter. Although no difference was observed among groups by the fifth measures, NSK SurgicXT/X-SG20Lwas significantly different from the others afterward. Consequently, the output torque can be inconsistent depending on the implant motor when the torque is applied repeatedly.

This study had some limitations in terms of the number of implant systems compared and the applied torque. To obtain more information, further experiments with other brands of implant motors and different torque levels will be needed.

CONCLUSION

Overall, the output torque of a surgical motor decreases gradually compared with the first torque when repeating the measures. The tendency of torque sinking differed according to the manufacturers. Within the limits of this study, the NSK surgical motor has a less consistent output than KaVo and Saeshin motors when the motor is overused. Therefore, clinicians should take care not to operate the surgical motor repeatedly, particularly at high torque.

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