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RESEARCH AND EDUCATION

Influence of different agents on the preload force of implant abutment screws

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ABSTRACT

Statement of problem. Screw loosening is a common problem in implant dentistry; however, information is sparse on the influence of different fluids on the screw threads.

Purpose. The purpose of this in vitro study was to investigate the influence of 4 different fluids and agents (saliva, blood, chlorhexidine [CHX] gel, and special sealing silicone) on the preload force of abutment screws.

Materials and methods. The test specimens (N=50) consisted of a thread sleeve resembling the implant, an abutment analog, and an abutment screw. The tightening of the screw with a torque wrench was performed in 5 steps (15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, and 35 Ncm). Each agent was applied in the lumen of the thread sleeve of 10 specimens. Ten dry thread sleeves served as the control. Comparisons between 2 independent groups were performed with the *t* test or Wilcoxon−Mann−Whitney test, as appropriate. The Bonferroni correction was used for multiple comparisons (α=.05).

Results. Preload forces increased linearly with the applied tightening torque for dry implant lumina, as well as for saliva, blood, silicone, and CHX gel in the implant lumina or thread sleeves. In general, none of the tested agents resulted in significantly higher preload forces compared with the dry control.

Conclusions. The agents investigated did not have any lubricant action on implant abutment screws. (J Prosthet Dent 2021;126:581-5)

A frequent complication of implant-supported restorations is loosening of the abutment screws.[1,2] The required correction depends on the type of retention of the restoration. While screw-retained crowns may merely need to be retightened, cemented crowns cannot easily be retightened,[3,4] with various techniques described to access the abutment screw.[5-7] However, these attempts may lead to loss of the restoration. A fractured abutment screw could even lead to loss of the implant.

When delivering implant-supported restorations, blood and saliva might enter the implant lumen; chlorhexidine (CHX) gel is applied to disinfect the lumen before the placement of the abutment; or the void between implant and abutment is sealed with a special silicone to prevent a biofilm from becoming established.[8-12] However, these agents located between the internal and external threads of the implant and abutment screw might influence the preload of the abutment screw. Friction in the thread might be reduced, which in turn might lead to a significantly higher preload.

The manufacturer has designed the screw so that the recommended tightening torque and the resulting preload will reach a maximum of 80% of the screw's elastic limit. If the elastic limit is exceeded, plastic deformation of the screw results in a decrease of preload and ultimately fracture of the screw. These complications can only be avoided by optimizing the abutment screw preload.[13] The preload is the force with which the abutment is loaded onto the implant with the abutment screw and

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Clinical Implications

The presence of fluids such as saliva or blood and agents such as CHX gel or sealing silicone in the internal thread of the implant lumen had little effect on preload force.

must not be confused with the torque force, which is weakened by friction during screw tightening.[14] The friction between the screw head and the screw head counterbore transfers the remaining force to the screw shank, with friction between the threads counteracting the torque force. Thus, a certain amount of residual torque will remain in the screw shank and will not be available to join abutment and implant.[15] The preload of screw connections is frequently enhanced in mechanical engineering by lubricants such as graphite or grease that reduce friction. (Czichos H, Habig KH. Tribologie-Handbuch - Tribometrie, Tribomaterialien, Tribotechnik 4th ed. Wiesbaden:Springer Vieweg; 2015. p. 417-40.) Studies that have analyzed saliva as a lubricant for abutment screw connections are sparse.[16]

Identifying factors that might influence the preload should reduce the screw loosening complication with implant-supported restorations. Therefore, the purpose of this in vitro study was to evaluate the influence of blood, CHX gel, saliva, and a sealing silicone on the preload of abutment screws. The null hypothesis was that the tested agents would not affect the preload of implant abutment screws.

MATERIAL AND METHODS

In total, 50 test specimens were custom manufactured, with an abutment screw, an abutment analog, and a thread sleeve resembling the implant (Fig. 1). All parts were turned with the same lathe (EmcoTurn 120, EmcoTronic TM02; EMCO Maier GmbH). The test specimens with different screw head angles and different numbers of thread turns were manufactured from titanium grade 5 with a metric M1.6 external thread. The abutment analog was made of titanium grade 5, and the screw head counterbore was centrally located. The screw head counterbores were turned with angles corresponding to the screw head angle of the abutment screws. The screw head angle (SHA) of 90 degrees and with 4 thread turns (TTs) was based on commercially available abutment screws (Fig. 2). In total, 50 abutment screws were analyzed in this study.

The measurement arrangement is shown in Figure 3. When the abutment screw was screwed into the thread sleeve and the screw head engaged its counterbore in the abutment analog, the collet chuck for the thread sleeve (Fig. 3, #5) was pulled toward the fixture of the abutment

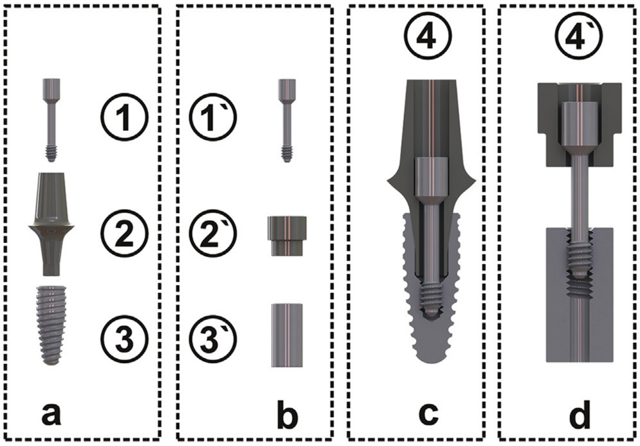

Figure 1. Original implant components and analogs tested (#1 and #1′abutment screw; #2 abutment and #2′abutment analog; #3 implant and #3′ thread sleeve; #4 and #4′ composition of components).

analog (Fig. 3, #9). Thus, the preload force was assembled between die components #5 and #9, as well as at the screw shank. To avoid components #5 and #9 approaching each other, they were joint-friction locked via the housing of measurement station (Fig. 3, #8), the cardan joint (Fig. 3, #7), and the combined force and torque sensor (Fig. 3, #6) (M-2396, 2 Nm/500 N as a one-off production; Lorenz Messtechnik GmbH).

In addition to the high simulation suitability of the implant components (Fig. 1, #1`,#2`,#3`), a correct geometric positioning of the components had to be ensured by the measurement arrangement. Therefore, a cardan joint (Fig. 3, #7) was placed between the sensor (Fig. 3, #6) and the measurement station (Fig. 3, #8). The cardan joint balanced possible axial deviations between the components, which could have led to undesirable enhancement of friction due to shearing forces, thereby influencing the preload force of the screw.[17]

Five torque wrenches (Biodenta Swiss AG) were used in this experiment. The torque was manually adaptable by turning the handle. Each torque wrench was calibrated to one of the following tightening torques: M_1=15 Ncm, M_2=20 Ncm, M_3=25 Ncm, M_4=30 Ncm, M_5=35 Ncm. The torque wrenches were electronically calibrated with a static torque sensor (D-2452, 1 Nm, Lorenz Messtechnik GmbH).

The screws were tightened with the torque wrench in 5 steps (15 Ncm, 20 Ncm, 25 Ncm, 30 Ncm, 35 Ncm) with the appropriate torque wrench calibrated before each step. The specified torque was exceeded several times until the digitally indicated value of the preload force no longer showed any changes. This was accomplished after a maximum of 3 times.

Each agent was tested with 10 thread sleeves, while 10 thread sleeves were left dry and served as the control. Thus, a total of 50 thread sleeves were analyzed in this

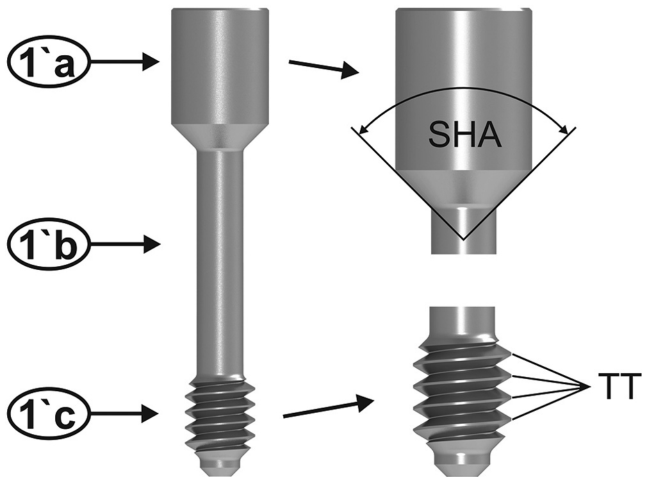

Figure 2. #1′a screw head; #1′b screw shaft; #1′c screw thread, SHA of 90 degrees; 4 TTs. SHA, screw head angle; TTs, thread turns.

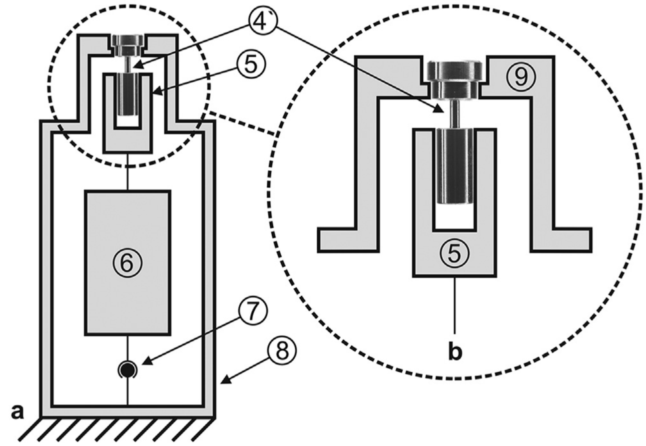

Figure 3. Measurement arrangement (a) with enlargement (b) (#4`: "simulated implant abutment connection"; #5: collet chuck for thread sleeve; #6: combined force and torque sensor; #7: cardan joint; #8: housing of measurement station; #9: fixture of abutment analog).

study. Expired whole blood obtained from a blood bank (Department of Transfusion Medicine, Johann Wolfgang Goethe University) which could no longer be dispensed to patients was used in the study. Artificial saliva (Saliva Natura; Medac GmbH) and chlorhexidine digluconate gel (1% GlaxoSmithKline Consumer Healthcare) were used for the present study. Furthermore, a sealing silicone (KIERO Seal; Kuss Dental, S.L.) was applied in a low-viscosity state, and the processing time was 2 minutes at 23 °C. After 5 minutes, the silicone had polymerized. All agents were solely applied into the lumen of the thread sleeve until the lumen was completely filled (Fig. 4), and the abutment analog was subsequently screwed as described previously.

Continuous variables were reported as mean and standard deviation. Comparisons between 2 independent groups were performed with the *t* test or Wilcoxon−Mann−Whitney test, as appropriate. The Bonferroni correction was used for multiple comparisons (α=.05). The statistical analysis was performed using a statistical software program (R 3.6.1; http://CRAN.R-project.org/).

RESULTS

Figure 5 and Table 1 give an overview of the preload forces for abutment screws with 4 TTs and SHA of 90 degrees for all the torques investigated (M_1=15 Ncm to M_5=35 Ncm) under all the tested circumstances (dry, saliva, blood, silicone, and CHX gel). Preload forces increased linearly with the applied tightening torque for dry implant lumina, as well as for saliva, blood, silicone, and CHX gel in the thread sleeves. For 17 of the 20 tested agents, no significant differences between the test and control groups were detected. Only the application of silicone at 2 torque levels (M_1 and M_3) and CHX at 1 torque level (M_5) showed statistically significant differences compared with the dry

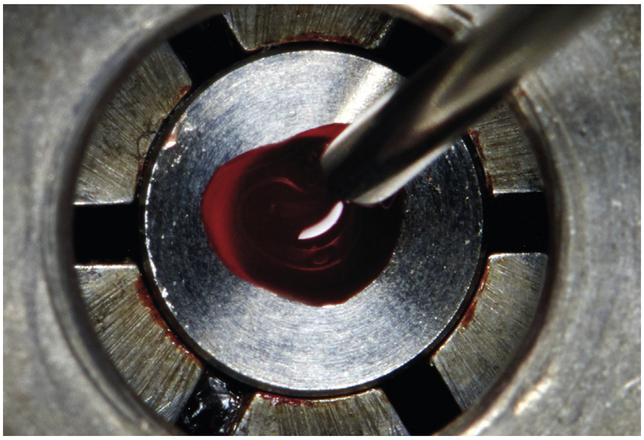

Figure 4. Applying agent (blood) into thread sleeve

control group. These *P* values are presented after Bonferroni correction for multiple testing in Table 2.

DISCUSSION

None of the agents served as a lubricant; therefore, the null hypothesis was accepted. The purpose of the present study was to investigate whether different fluids, such as blood, CHX gel, saliva, and a sealing silicone, might influence the preload force of abutment screws. The preload forces rose linearly with the applied tightening torque irrespective of whether the implant lumen was dry or filled with any of the agents investigated. None of the applied agents increased the preload forces compared with a dry implant lumen. Only at 3 torque levels, did silicone and CHX show significant influences on the preload forces compared with the dry control group. Each agent was tested with 10 different thread sleeves at 5 different torque levels (M_1-M_5). A total of 250 torque

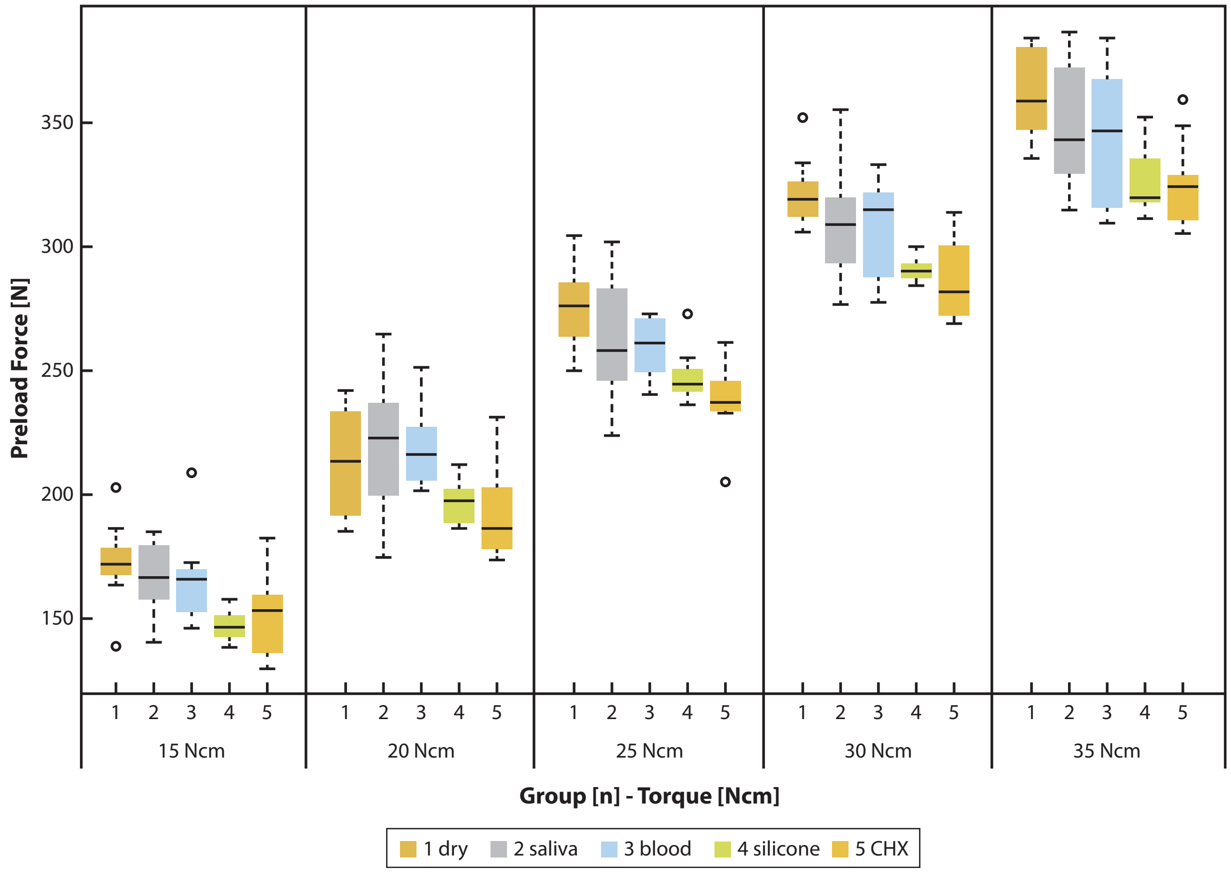

Figure 5. Preload forces—M1.6×0.35, SHA 90 degrees, 4 TTs (titanium grade 5), screw head counterbore (titanium grade 5), threaded sleeve (titanium grade 4) with different agents (1-6) and different torques (M_1=15 Ncm-M_5=35 Ncm). CHX, chlorhexidine; TTs, thread turns.

Table 1. Median, maximum, and minimum preload values for implant abutment screws with 4 TTs and SHA of 90 degrees with different agents and different tightening torques

TTs=4, SHA = 90 degrees	15 Ncm		20 Ncm		25 Ncm		30 Ncm		35 Ncm	
Dry	171.83 N	202.77 N	213.26 N	242.06 N	275.90 N	304.29 N	318.99 N	352.09 N	358.70 N	383.82 N
		138.96 N		184.88 N		249.97 N		305.88 N		335.38 N
Saliva	166.54 N	184.88 N	222.58 N	264.46 N	257.88 N	301.88 N	309.03 N	355.36 N	343.21 N	386.63 N
		140.34 N		174.63 N		223.70 N		276.43 N		314.82 N
Blood	165.72 N	208.70 N	216.20 N	251.35 N	261.15 N	272.81 N	314.87 N	333.08 N	346.77 N	383.64 N
		145.79 N		201.86 N		240.27 N		277.54 N		309.54 N
Silicone	146.34 N	157.75 N	197.55 N	211.95 N	244.16 N	272.68 N	290.25 N	299.96 N	319.71 N	352.23 N
		138.42 N		186.34 N		236.23 N		284.26 N		311.17 N
CHX gel	153.30 N	182.99 N	186.44 N	231.13 N	237.10 N	261.51 N	281.72 N	313.90 N	323.93 N	359.80 N
		129.79 N		173.77 N		205.10 N		268.90 N		305.34 N

CHX, chlorhexidine; SHA, screw head angle; TTs, thread turns.

levels were analyzed. Significant differences between the test groups and the control group occurred in only 3 of 20 group comparisons, possibly because of the influence of the material. However, these effects are difficult to explain as they did not appear to follow a pattern.

Jörn et al[16] used finite element analysis to investigate the influence of lubricant action on screw preload force and stresses in the implant abutment complex, calculating from different friction coefficients the lubricant action of saliva (μ=0.2-0.3) and dry conditions (μ=0.4-0.5). The abutment screw was virtually tightened with a

Table 2. Statistically significant differences between the groups after Bonferroni correction for multiple testing

15 Ncm		25 Ncm		35 Ncm	
Groups	*P*	Groups	*P*	Groups	*P*
Dry/silicone	.004	Dry/silicone	.002	Dry/CHX gel	.001

CHX, chlorhexidine.

torque of 25 Ncm. However, the assumption of the lubricant action of saliva was not consistent with the results of the present study.[16]

Limitations of the present study included that the access of the tested agent was restricted to the implant lumen. In the present study, the tested agents have only been applied into the lumen of the implant, which frequently occurs in daily practice. However, it remains unclear whether the preload force might increase, when the tested agents were also applied into the abutment. Further research is suggested to analyze this topic, as well as a lubricant action of the tested agents on surface finished screws such as diamond-like carbon (DLC), gold-coated, or anodized screws.

CONCLUSIONS

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

1. The agents under investigation had no lubricant action on the threads of the implant abutment complex.
2. Although dry conditions are preferred, the penetration of agents such as blood and saliva into the implant lumen during treatment appears to have no negative influence on the preload force.
3. The often-recommended use of CHX gel and silicone to prevent bacterial contamination had no effect, with only 3 exceptions.
4. The presence of the tested agents in the implant lumen did not appear neither to reduce, nor to enhance the preload force.

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