The Influence of Tightening Sequence and Method on Screw Preload in Implant Superstructures

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This study evaluated the effect of six screw-tightening sequences and two tightening methods on the screw preload in implant-supported superstructures. The preload was measured using strain gauges following the screw tightening of a metal framework connected to four implants. The experiment included six sequences (*[1]* 1-2-3-4, *[2]* 4-2-3-1, *[3]* 4-3-1-2, *[4]* 1-4-2-3, *[5]* 2-3-4-1, and *[6]* 3-2-4-1), two methods (one-step, three-step), and five replications. Significant differences were found between tightening sequences and methods. In the three-step method, a higher total preload was found in sequences 2 (312 ± 85 N), 3 (246 ± 54 N), and 4 (310 ± 96 N). In the one-step method, a higher total preload was found in sequences 1 (286 ± 94 N), 5 (764 ± 142 N), and 6 (350 ± 69 N). It is concluded that the highest total screw preload was achieved when anterior implants of the superstructure were first tightened in one step, followed by posterior implants. *Int J Prosthodont 2014;27:76–79. doi: 10.11607/ijp.3306*

Prosthetic screw loosening occurs when the internal preload is lost as a result of external forces (external preload) and misfit of the superstructure.[1] The influence of the tightening sequence on both external and internal preload may vary according to the degree of superstructure misfit. The external preload differed significantly between different tightening sequences in a clinically fit superstructure.[2] Furthermore, Choi et al[1] reported that a two-step tightening method resulted in a significantly higher external preload than a one-step method. No studies to date have investigated the influence of tightening sequences combined with a three-step method on the screw's internal preload in implants with internal abutment connections.

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The aim of this study was to evaluate the effect of different screw-tightening sequences on the screw preload in implant-supported superstructures and to compare the preload between a three-step and a one-step tightening method.

Materials and Methods

A stainless steel master cast with dimensions of 68 × 54 × 20 mm was machined to represent a mandibular arch form. Four implant fixtures (4.1 × 14 mm, Straumann) were embedded into the master cast with cyanoacrylate adhesive cement and sequentially numbered from 1 to 4 from left to right (Fig 1). One linear strain gauge (KFG-02-120-C1-11L1M2R, Omega Engineering) was attached to each implant neck surface. The strain gauges were wired into a quarter-bridge configuration and fed into a 10-channel digital strain meter (DMD-22, Omega Engineering). A direct implant-level impression was made using a polyether impression material (Impregum Penta, 3M ESPE) and poured with vacuum-mixed Die-Keen dental stone. A one-piece casting method was used to fabricate a metal superstructure, and the passivity of fit was evaluated on the cast and the master cast by alternate finger pressure and a one-screw test in conjunction with an explorer.[3] The vertical gap between the implant and framework was measured after complete seating and tightening of prosthetic screws using a traveling microscope at a magnification of ×10 (Titan). A mean of three points of measurements for each implant was calculated.

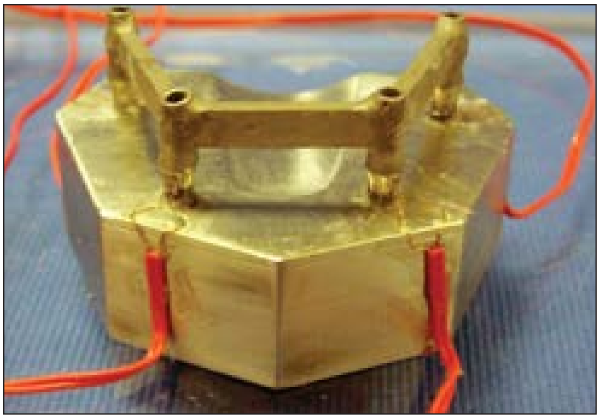

Fig 1 The metal framework seated on the master metal cast (1 to 2 and 3 to 4 = 28 mm, 2 to 3 = 26 mm).

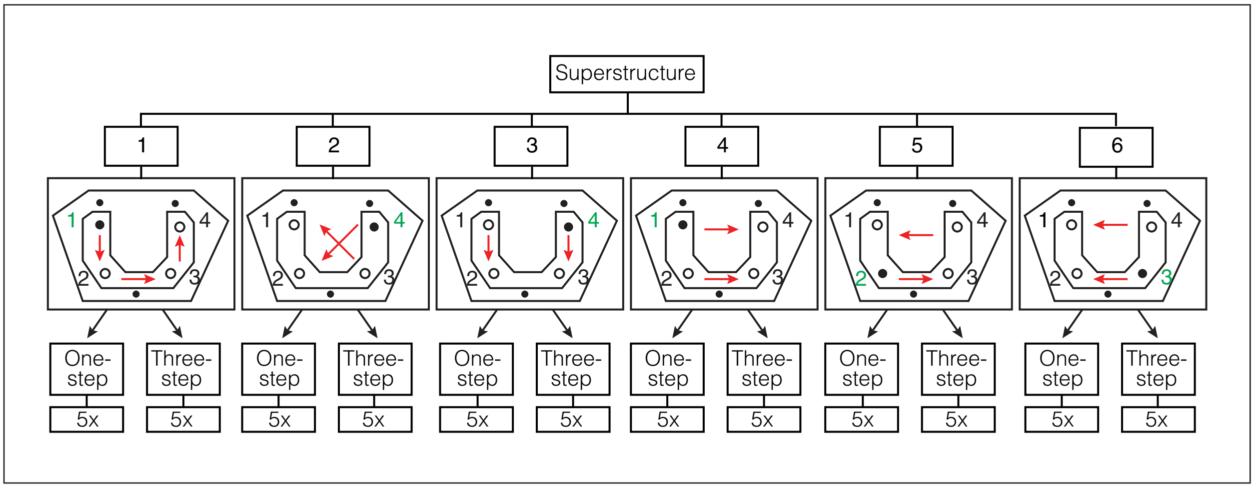

Fig 2 The superstructure was tightened in six different sequences (the first implant tightened in each sequence is in green). Each sequence included two methods (one-step and three-step). Each experiment was replicated five times.

The calibration of the implants using dead weight indicated a linear relationship between strain and load. The preload for each implant was measured after fitting the framework in six different tightening sequences (*[1]* 1-2-3-4, *[2]* 4-2-3-1, *[3]* 4-3-1-2, *[4]* 1-4-2-3, *[5]* 2-3-4-1, and *[6]* 3-2-4-1) using a digital torque gauge (STS-0003 series, Chatillon). Each tightening sequence consisted of two tightening methods (one-step [0–15 Ncm] and three-step [0–5–10–15 Ncm]) for a total of 60 tightening experiments (six sequences × two methods × five replications, Fig 2). The experimental runs were randomized between sequences and methods. A new prosthetic screw was used for each sequence and method, whereas the same screw was used in the replication experiments. The preload data were analyzed using a two-way analysis of variance at a .05 level of statistical significance.

Results

The vertical gap measurements were 27.9 μm, 141.4 μm, 43.2 μm, and 41.5 μm for implants 1 to 4, respectively. All of the implants showed a positive but variable preload (ie, compression between the framework and the implant) except for implant no. 2, which showed negative values (ie, tension between the framework and the implant) (Table 1). The total sum of the preload from the four implants was calculated to represent the total clamping force (compressive) of the framework. There were significant differences in the framework preload among the different tightening sequences and methods. In the three-step method, the preload was significantly higher in sequences 2 (311.5 ± 84.6 N), 3 (245.9 ± 54.1 N), and 4 (309.8 ± 95.5 N). In the one-step method, the preload was significantly higher in

Table 1 Screw Preload at Each Tightening Sequence and Method (n = 5)

Tightening sequence	Tightening method	Mean (SD) at each implant No. 1	No. 2	No. 3	No. 4	Total preload (N)
1	Three-step	94.9 (7.7)	−296.6 (5.3)	315.8 (10.5)	67.2 (20.3)	181.3 (26.1)
	One-step	78.4 (9.7)	−298.0 (3.0)	388.3 (38.4)	116.8 (50.0)	285.5 (94.0)
2	Three-step	109.1 (15.9)	−263.7 (20.8)	375.8 (24.3)	90.2 (36.6)	311.5 (84.6)
	One-step	97.8 (26.5)	−338.3 (3.6)	323.6 (28.7)	44.4 (78.4)	127.5 (99.5)
3	Three-step	95.8 (8.8)	−289.2 (4.7)	354.4 (13.7)	85.0 (33.0)	245.9 (54.1)
	One-step	109.4 (9.1)	−287.1 (5.9)	369.7 (32.8)	−15.7 (79.5)	176.4 (49.1)
4	Three-step	108.5 (12.1)	−288.5 (4.2)	358.8 (28.0)	131.0 (56.7)	309.8 (95.5)
	One-step	39.4 (21.0)	−285.6 (5.5)	265.4 (22.8)	170.2 (31.4)	189.6 (67.2)
5	Three-step	75.1 (10.9)	−323.6 (1.6)	262.8 (13.8)	58.5 (44.1)	73.0 (63.2)
	One-step	127.8 (34.6)	−279.7 (51.9)	800.4 (65.8)	114.8 (21.5)	763.4 (141.4)
6	Three-step	53.4 (15.1)	−303.3 (2.9)	277.1 (18.7)	72.8 (37.0)	100.1 (58.1)
	One-step	95.4 (20.9)	−379.7 (3.3)	536.4 (40.0)	97.6 (12.8)	349.7 (68.7)

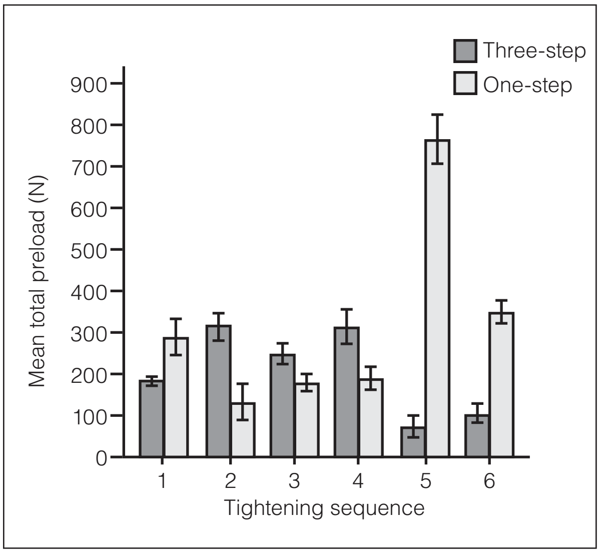

Fig 3 The total preload in different tightening sequences and methods.

Table 2 A Representative Example of Total Preload in Tightening Sequences 4 and 5 in Both Methods of Tightening at Each Tightening Repetition

Tightening repetition	Tightening sequence 4, Total preload (N): Three-step method	One-step method	Tightening Sequence 5, Total preload (N): Three-step method	One-step method
1	175.18	143.51	-25.01	552.31
2	280.04	115.89	69.04	701.80
3	317.52	244.48	66.65	804.64
4	337.44	170.16	112.26	918.94
5	439.09	274.22	142.33	839.47

sequences 1 (285.5 ± 94 N), 5 (763.4 ± 141.4 N), and 6 (349.7 ± 68.7 N). Sequence 5 in the one-step method resulted in a significantly higher preload than all of the other sequences, but in the three-step method showed the lowest preload values compared with the other sequences ($P < .05$) (Fig 3). There was a trend of increased preload upon repeated tightening of the same prosthetic screw (Table 2).

Discussion

In general, the preloads measured in this study compared well with other published reports with similar methodology.[2,3] Although the preload was expected to register similarly on all implants when they were subjected to equal torque, a considerable variation between implants was observed. The variation in the internal preload registered between implants was likely due to the variations in the contact between the framework and implants as a function of unavoidable casting inaccuracy. Such variations in contact between the framework and implants were commonly reported even when the framework was judged clinically passive.[1,2] When torque is applied to the screw, the screw elongates and a compressive force (clamping force) builds up, pulling both the neck of the implant and the framework as a result of the elastic recovery of the elongated screw. As a consequence, the internal preload will be first induced in implants with which the framework is in close contact, whereas the internal preload on the other implants will only build up when the gap between the framework and these implants is closed.[4] The rational for calculating the sum of screw preload was to analyze the total clamping force created in the superstructure after tightening.

The tensile forces (joint separating forces) registered in implant no. 2 were most likely the result of a higher discrepancy between the framework and implant, confirming the results of the vertical gap measurements. Similar tensile forces related to superstructure misfit have been previously observed.[4] The only time a positive preload was registered in implant no. 2 was during the first step of tightening sequence 5 (2-3-4-1). When torque was first applied to implant no. 2, the gap between the framework and implant was closed and a contact was established resulting in compressive forces. However, as the other implant screws were torqued, the distortion of the framework created tensile forces (negative preload) on implant no. 2 and the gap reopened.

Duyck et al[4] stated that the distortion of the prosthesis as a result of screw tightening could create extra tensile forces on the abutments and inhibit the induction of a proper internal preload. In this study, the misfit of the framework, especially in implant no. 2, resulted in similar behavior.

The significant influence of the tightening sequences on the internal preload agrees with Smedberg et al.[2] The one-step method resulted in a higher preload compared with the three-step method in tightening sequences 1, 5, and 6 but was significant only in sequence 5. This finding implies that tightening the implant that exhibits the largest misfit and the implant adjacent to it first reduces the gap more effectively and increases the internal preload on the other implants. However, the same sequences in a three-step method resulted in a much lower preload, possibly because the lower torque initially applied was not sufficient to reduce the gap at the beginning of the sequence. Furthermore, in sequences 2, 3, and 4, where the gap was not reduced early in the sequence, a three-step method achieved a higher preload compared with the one-step method. Another study that used a tightening sequence similar to sequence 5 in this study found that a two-step method resulted in a higher preload stress (external preload) on the framework compared with the one-step method, thereby corroborating the results of this study.[1]

Tzenakis et al[5] suggested that a higher preload is achieved after the repeated torque of a prosthetic screw possibly because of the reduction in friction between the components. A similar observation was made in this study.

Conclusion

Within the limitations of this study, the one-step tightening method is recommended when the largest implant gap is reduced early in the tightening sequence, as in sequences 1, 5, and 6. The highest framework preload was achieved when the tightening sequence began with the implant that exhibited the largest misfit and with the implant adjacent to it in the one-step method, as in sequence 5. A trend of increased preload with repeated screw use was observed.

Acknowledgment

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References

1. Choi JH, Lim YJ, Kim CW, Kim MJ. The effect of different screw-tightening techniques on the stress generated on an internal-connection implant superstructure. Int J Oral Maxillofac Implants 2009;24:1045–1053.
2. Smedberg JI, Nilner K, Rangert B, Svensson SA, Glantz SA. On the influence of superstructure connection on implant preload: A methodological and clinical study. Clin Oral Implants Res 1996;7:55–63.
3. Tan KB, Nicholls JI. The effect of 3 torque delivery systems on gold screw preload at the gold cylinder-abutment screw joint. Int J Oral Maxillofac Implants 2002;17:175–183.
4. Duyck J, Van Oosterwyck H, Vander Sloten J, De Cooman M, Puers R, Naert I. Pre-load on oral implants after screw tightening fixed full prostheses: An in vivo study. J Oral Rehabil 2001;28:226–233.
5. Tzenakis GK, Nagy WW, Fournelle RA, Dhuru VB. The effect of repeated torque and salivary contamination on the preload of slotted gold implant prosthetic screws. J Prosthet Dent 2002; 88:183–191.