A STUDY OF THE EFFECT OF AN ANTI-ROTATIONAL INNER POST SCREW SYSTEMS ON ABUTMENT SCREW LOOSENING FOR SINGLE IMPLANT : PART 1

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Statement of problem. Implant abutment screw joints tend to loosen under clinical conditions. Abutment screw loosening results in loss of preload in function.

Purpose. Anti-rotational inner post screw (ARIPS) systems were compared with conventional abutment screws to reduce screw loosening. Reverse torque values were evaluated.

Material and methods. 32 implant assemblies (Warentec, Co, Ltd, Seoul, Korea) were organized as the 30-Ncm-torque conventional groups and 30-Ncm-torque ARIPS groups in external and internal system. The specimens were tested to 10^6 cycles at a load of 200N. Preload reverse torque, postload reverse torque, and the ratio of postload reverse torque to preload reverse torque were evaluated. The data were analyzed with unpaired t-test in external and internal systems.

Results. In the ratio of postload reverse torque to preload reverse torque, the ARIPS groups showed significant differences than the conventional screw group in both external and internal system.

Conclusion. Within the limitations of this study, abutment screw loosening was effectively reduced using ARIPS system.

Key Words

Dental implant, abutment screw loosening, anti-rotational inner post screw (ARIPS) system, reverse torque values

Since Brånemark and his colleagues[1] had introduced the concept of osseointegration, dental implants have been successfully used for fully and partially edentulous patients. The use of single implant has continued to increase and become refined.

One of the common problems of single dental implant prostheses is the loosening of the screw, and the problem is especially more common in external connection types.[2-6] When it occurs, patients complain soreness at the interface between the soft tissue and the implant, swelling, and / or fistula formation, difficulty in mastication, and prosthetic instability.

From a biomechanical point of view, the 2 important methods used to counteract screw loosening, that is the incorporation of an anti-rotational elements and the screw joint preload.[7] The two methods can be combined to reinforce each other.

As to the anti-rotational elements, Brånemark[8] first introduced the implant external hexagon design. With the introduction of single-tooth implant-supported prosthesis, prosthesis indexing and anti-rotational mechanisms have been added. And larger external hexagons, internal octagons, 1-degree Morse taper, frictional fit abutment, and the spline structure (close-sliding fit) were introduced. Bickford[9] reported on methods to prevent screw loosening in vibration loosening by making slots, designing geared faces, and using lock wires or pins. Artzi et al[10] reported a screw lock method that a long hexagonal titanium bar was inserted into the hexagon of a screw head, and resin fixed a screw. Cavazos and Bell[11] advocated the application of hand torque, the addition of undercuts in the internal surface of the screw access chamber, and the injection of impression material. Aboyoussef et al[12] proposed a method that reduced screw loosening by making four milled notches around standard abutments.

The other important mechanical factor is the screw joint preload, which is defined as the tensile force that is built up in the abutment screw as a product of screw tightening.[13,14] It is dependent on the applied torques and additionally on the component material, screw head and thread design, and surface roughness.[13,15] The magnitude of the torques is limited by the screw yield strength and the strength of the bone/implant interface.[15,16]

In this paper, the concept of post screw and locking sleeve was introduced. The screw head was fabricated as a long post, so the inside of the abutment was filled. Notches were carved into the side of the post screw and corresponding abutment section. The resin-locking sleeve was located between the two notches. An implant assembly using a post screw was termed an anti-rotational inner post screw system, hereafter called an ARIPS system. This study used ARIPS systems to reduce the abutment screw loosening.

MATERIAL AND METHODS

32 implant assemblies, 16 external hexagons and 16 internal octagons, were used (Table I). These assemblies were organized as the 30-Ncm-torque conventional screw groups (30C-Ex, 30C-In), 30-Ncm-torque ARIPS groups (30Ar-Ex, 30Ar-In) in external and internal systems. Each assembly was consisted of a 4.3 × 10 mm threaded, rough surface fixture (Warentec, Co, Ltd, Seoul, Korea),

Table I. Connection structure and tightening torque for specimen groups

Group	30C-Ex	30Ar-Ex	30C-In	30Ar-In
Connection	External hexagon	External hexagon	Internal octagon	Internal octagon
Abutment screw	Conventional	ARIPS	Conventional	ARIPS
Torque (Ncm)	30	30	30	30
N	8	8	8	8

ARIPS = anti-rotational inner post system.
30C-Ex = 30Ncm torque-Conventional abutment screw-External hexagon group; 30Ar-Ex = 30Ncm torque-ARIPS screw-External hexagon group; 30C-In = 30Ncm torque-Conventional abutment screw-Internal octagon group; 30Ar-In = 30Ncm torque-ARIPS screw-Internal octagon group.
N = Number of specimens in each group.

6 mm abutment (Warentec, Co, Ltd), abutment screw, and superstructure jig (15 × 7 × 4 mm). The abutment screws were conventional screws (Warentec, Co, Ltd) and newly designed ARIPS screws (Figs 1 and 2). The ARIPS screws were fabricated using the same titanium alloy used as conventional screws and were tightened with specially designed ARIPS screwdriver (Fig. 3). The superstructure jigs (Fig. 4) were manufactured with reinforced stainless steel and the internal diameter of central hole of the jig was milled within an error of 0.01 mm. Thirty-degrees inclined planes were applied to both sides, to transfer lateral forces to implant assembly.

Fig. 1. Experimental ARIPS (anti-rotational inner post system) screws in internal octagons (left) and external hexagons (right).

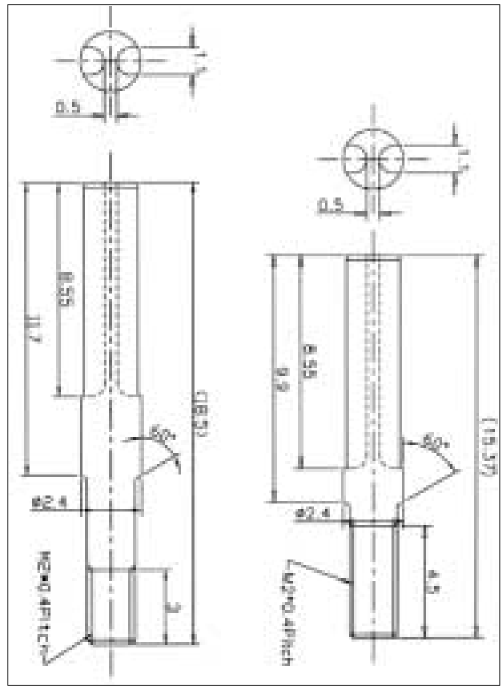

Fig. 2. Geometric dimensions of ARIPS (anti-rotational inner post system) screws of internal octagons (left) and external hexagons (right).

Fig. 3. Experimental ARIPS (anti-rotational inner post system) screw driver, which screwed the implant deeply into a screw notch with two grooves.

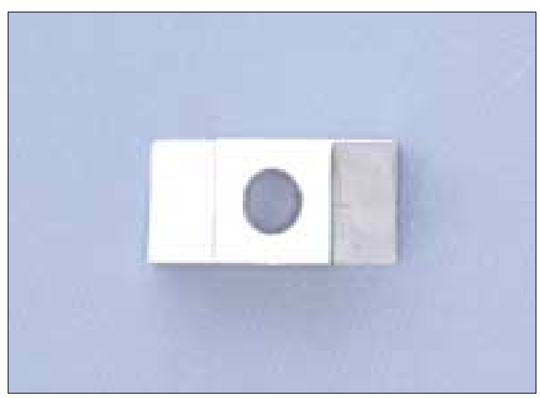

Fig. 4. Experimental superstructure jig. Thirty-degrees inclined planes were applied to both sides to transfer lateral forces to implant assembly.

Fig. 5. ARIPS (anti-rotational inner post system) screw notch. (A) 1.5cm (B) 2 cm.

Fig. 6. Sectional view of resin locking sleeve of ARIPS (anti-rotational inner post system) screw. The composite resin (Heliomolar HB) was filled in the locking sleeve.

Fig. 7. Universal testing machine. This machine was an impact tester with a pressure gauge attached to the filter controller, and included load cells.

After applying a hand-tightening force on implant assembles, the specimens were embedded with clear resin (Ortho-Jet; Lang Dental Mfg. Co, Wheeling, Ill, USA) in a 20 × 20 × 30 mm mold using a surveyor. The resin was a polymethyl methacrylate resin exhibiting similar values in the modulus of elasticity to human trabecular bone (1.95 GPa).[17] The implants were placed so that 3 mm of bone resorption was simulated[18], and the surveyor was used to ensure that the implants were placed perpendicular to the base.

The fabrication process of an ARIPS resin-locking sleeve is as follows: implant assembly was tightened with a target torque force. Tightening torque was applied, and according to a protocol suggested by Dixon et al[19] and Breeding et al[20] 10 minutes later the screws were retightened to the same torque to minimize embedment relaxation. Then, the notch position was marked on the abutment. Next, the implant assembly was separated (measuring preload reverse torques). Finally, notches on the abutment were formed using a high-speed diamond bur (Fig. 5). Tightening torque was reapplied and the composite resin (Heliomolar HB; Ivoclar vivadent, Auckland, New Zealand) was filled in the locking sleeve (Fig. 6). Abutment screw tightening was applied using a digital torque gauge (MGT50; MARK-10 Corp, Copiague, NY). Because the torque controller recommended by manufacturers could have resulted in differences in the tightening torque, the application of a precise tightening torque was attempted using the digital torque gauge.

To apply cyclic loads, a universal testing machine (Fig. 7) was used at room temperature. This machine was an impact tester with a pressure gauge attached to the filter controller, to precisely measure and control the fluid pressure. The loading system included load cells (Loadcell DBBP-100; Bongshin Loadcell Co, Seongnam, Korea) attached for the purpose of measuring applied loads and detecting any changes in load.

200 N of cyclic load was applied and load was limited to a tolerance of within 10%. 18 Richter et al [21] reported that the maximum occlusal force of implant prostheses for a molar region was 121.1 ±69.6 N. The loading force of this study was within the range of posterior occlusal force for fixed prostheses supported by implants (35-330 N).[22] The loading stylus was cone shaped, made of stainless steel, and had a 3 mm diameter hemisphere tip. The loading rate was 0.87 Hz and the number of cycles was 1.0×10^6. A target of 10^6 cycles could be estimated 1 year of simulated function. This estimation was that a person has 3 episodes of mastication per day, each 15 minutes in duration at a masticatory rate of 60 cycles per minute (1 Hz). This is equivalent to 2,700 cycles per day, roughly 10^6 per year.

Postload reverse torque was measured using a digital torque gauge under the jig-assembled conditions. The process that the jig held the sleeve to the side was considered similar as that the prosthesis was clinically attached to an abutment.

SPSS Statistical Software for Windows (release 12.0, SPSS, Chicago, Ill, USA) was used for statistical analysis. Preload reverse torque, postload reverse torque, and the percentage of postload reverse torque to preload reverse torque were evaluated. The data were analyzed with unpaired t-test in external and internal systems (P<. 05).

RESULTS

Preload reverse torque and postload reverse torque values were evaluated (Table II and III).

4 screws (3 conventional screws, 1 ARIPS screws) were fractured during load application at the interface between the screw shank and the first thread.

The ratio of post load reverse torque to preload reverse torque in external system was established (Table IV) and statistical results of unpaired t- test were established (Table V). There are significant differences between the conventional screw group and ARIPS group in external system (P<. 05). And the ratio of post load reverse torque to preload reverse torque in internal system was established (Table VI) and statistical results of unpaired t- test were established (Table VII).

Table II. Preload reverse torque values of specimens (Ncm)

Group	30C-Ex	30Ar-Ex	30C-In	30Ar-In
Preload torque	27.2	24.4	27.6	27.2
	27.8	27.1	26.7	25.7
	29.1	31.9	31.7	32.0
	23.8	24.2	31.2	27.5
	29.6	27.5	27.9	27.2
	25.1	26.6	28.6	28.8
	29.6	27.4	25.5	29.2
	28.7	26.6	27.3	27.6

30C-Ex = 30Ncm torque-Conventional abutment screw-External hexagon group; 30Ar-Ex = 30Ncm torque-ARIPS screw-External hexagon group; 30C-In = 30Ncm torque-Conventional abutment screw-Internal octagon group; 30Ar-In = 30Ncm torque-ARIPS screw-Internal octagon group.

Table III. Postload reverse torque values of specimens (Ncm)

Group	30C-Ex	30Ar-Ex	30C-In	30Ar-In
Postload torque	-	23.5	17.5	22.5
	18.0	21.0	8.5	33.5
	-	18.0	27.0	22.5
	-	34.5	14.5	27.5
	22.0	25.0	15.0	19.5
	20.0	26.0	21.5	25.5
	24.0	24.5	16.5	-
	14.5	23.0	16.5	21.0

30C-Ex = 30Ncm torque-Conventional abutment screw-External hexagon group; 30Ar-Ex = 30Ncm torque-ARIPS screw-External hexagon group; 30C-In = 30Ncm torque-Conventional abutment screw-Internal octagon group; 30Ar-In = 30Ncm torque-ARIPS screw-Internal octagon group.
- : Abutment screws were fractured during cyclic loading procedures.

Table IV. The percentage of postload reverse torque to preload reverse torque in external groups

Group	30C-Ex	30Ar-Ex
Post / Pre	-	0.9631
	0.6474	0.7749
	-	0.5642
	-	1.4292
	0.7432	0.9090
	0.7968	0.9774
	0.8108	0.8941
	0.5052	0.8645
Mean	0.7007	0.9217
Std Dev	(±0.1267)	(±0.2427)

30C-Ex = 30Ncm torque-Conventional abutment screw-External hexagon group; 30Ar-Ex = 30Ncm torque-ARIPS screw-External hexagon group.
Post / Pre = postload reverse torque / preload reverse torque.
- : Abutment screws were fractured during cyclic loading procedures.

Table V. The results of Unpaired t-test in external groups

Group	N	Mean	Std Dev	Std Error	T	DF	P
30C-Ex	5	0.701	0.127	0.057	-2.15	10	.0290*
30Ar-Ex	8	0.922	0.244	0.086	-2.15	10	

30C-Ex = 30Ncm torque-Conventional abutment screw-External hexagon group; 30Ar-Ex = 30Ncm torque-ARIPS screw-External hexagon group.
* = significantly different (*P*<0. 05).

Table VI. The percentage of postload reverse torque to preload reverse torque in internal groups

Group	30C-In	30Ar-In
Post / Pre	0.6340	0.8272
	0.3148	1.3035
	0.8517	0.7031
	0.4647	1.0000
	0.5376	0.7169
	0.7517	0.8854
	0.6470	-
	0.6043	0.7608
Mean	0.6012	0.8853
	(±0.1653)	(±0.2115)

30C-In = 30Ncm torque-Conventional abutment screw-Internal octagon group; 30Ar-In = 30Ncm torque-ARIPS screw-Internal octagon group.

- : Abutment screws were fractured during cyclic loading procedures.

Table VII. The results of Unpaired t-test in internal groups

Group	N	Mean	Std Dev	Std Error	T	DF	P
30C-In	8	0.601	0.166	0.059	-2.87	11	.0008**
30Ar-In	7	0.885	0.212	0.080	-2.87	11	

30C-In = 30Ncm torque-Conventional abutment screw-Internal octagon group; 30Ar-In = 30Ncm torque-ARIPS screw-Internal octagon group.

** = significantly different (P〈0.01).

There are significant differences between the conventional screw group and ARIPS group in internal system (P<. 05). The 30-Ncm-toruqe ARIPS groups showed significant differences than the 30-Ncm-toruqe conventional screw groups in both external and internal systems.

DISCUSSION

The ratio of postload reverse torque to preload reverse torque was clinically important references to prevent the loss of preload. In the ratio of postload reverse torque to preload reverse torque, the external and internal groups with the ARIPS system displayed significant differences than conventional screw groups.

Based on the estimated results, the ARIPS system presented superior results under the same preload conditions to the conventional screw after loading. The reason of the efficacy of ARIPS systems might be that the ARIPS screw was fitted with a long post that expanded the contact area to the abutment, and the presence of the locking sleeve created a more stable engagement of anti-rotational element and an increased moment arm.

A few number of abutment screws were fractured during load application at the interface between the screw shank and the first thread. This result coincided with a report on stress distribution of preloaded screws by Alkan et al in 2004.[23]

In the previous stage of the experiment, the differences of the notch joints between the hand tightening and the mechanical tightening were happened. The broader abutment notch than screw notch can guarantee a locking area. To maximize the effect of ARIPS screw, additional studies, on size of a notch and strength of locking resin, are required.

Reverse torque values were not evaluated in clinical trials, so there are limitations of this method in applications. And it was necessary to reexamine the effect on the abutment screw when it was retightened. Weiss et al[24] reported that repeated opening and closing of abutment screws caused progressive loss of torque retention. Tzenakis et al[25] reported that in gold prosthetic screw with repeated torque tightening, the gradual elimination of micro roughness and allowed a greater amount of preload. Further studies are required on the effects of repeated torque tightening on a titanium abutment screws.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

1. There were significant differences in reverse torque values between the conventional screw groups and ARIPS groups after cyclic loadings.
2. In the percentage of postload reverse torque to preload reverse torque, The 30-Ncm-toruqe ARIPS groups showed significant differences than the 30-Ncm-toruqe conventional screw groups in external system.
3. In the percentage of postload reverse torque to preload reverse torque, The 30-Ncm-toruqe ARIPS groups showed significant differences than the 30-Ncm-toruqe conventional screw groups in internal system.

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