Development of Implant Magnetic Keepers

– Study on the screw loosening by repeated load-

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Introduction

Implant materials and techniques have markedly improved in recent years. An implant overdenture with magnetic attachments has excellent retention mechanism, and has been drawing attention as one of the implant treatments.

We investigated attractive force and surface treatment methods to develop safe and practical magnetic implant system, and devised an ideal prototype keeper. Mechanical analysis was performed using three-dimensional finite element method to assess stress-bearing ability of this implant system for further optimization of a keeper.

A magnetic attachment is incorporated in the overdenture in the present implant system. External force is applied to an implant keeper during mastication due to the characteristics of an implant overdenture. The abutment was fixed to a fixture using an abutment screw, and the implant keeper was fixed on the top. The prototype implant keeper was fixed to an abutment by a screw structure of a keeper.

The axial force in the tensile direction in a bolt created by tightening the screw and compressive force in a tightened substance are combined and balanced when there is no external force. However, these forces decrease by the application of external force, resulting in loosening of a screw. Loosening of a keeper during functioning may cause impairment in function as an attachment, and increase a risk of accidental ingestion and aspiration of a keeper.

Objective

Repeated load was applied on a keeper of the implant to investigate loosening at the junction between a keeper and abutment during function.

Materials and Methods

1.Materials

An abutment and a keeper that fit into the fixture of commercially-available implant system (GENESIO, GC, Tokyo) were devised. Magnetic stainless steel SUSXM 27 was used for a prototype implant keeper, 6Al-4V-Ti alloy was used for a special jig, and pure titanium (JIS IV) was used for a fixture. The head of a GENESIO system abutment screw was shortened by the thickness of a keeper. A fixture and a special abutment were fixed with abutment screws according to the GENESIO system, and a special abutment and prototype implant keeper were fixed by a screw consisting of the inner part of the abutment and outer surface of a keeper. An implant keeper was designed to be completely stored in the abutment to avoid deformity and edge roll-off due to long-term use (Fig. 1).

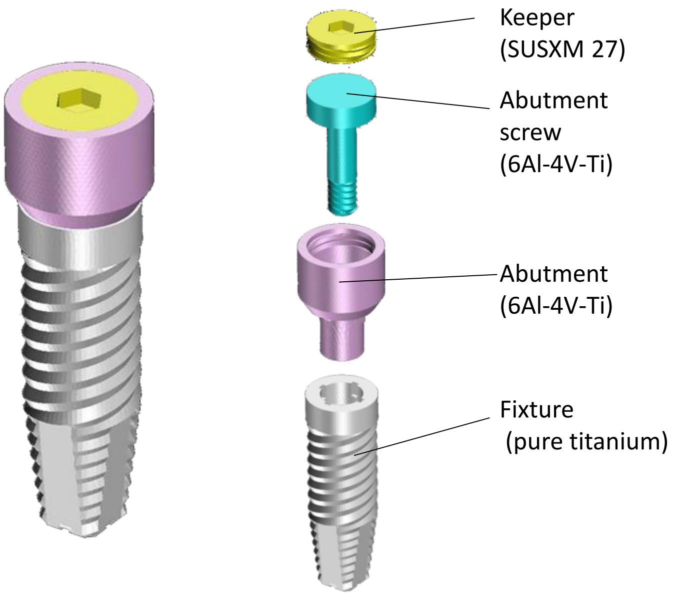

Figure 1. The structure of a prototype implant system

1) Prototype implant keeper

An implant keeper was designed in the cylindrical shape to match the size of a commercially-available magnetic attachment (GIGAUSS D600, GC, Tokyo). A keeper had a hexagonal screw hole with 1.3 mm in diameter and 0.8 mm in depth, and screw structure was added to the outer surface of a keeper. The hole center model of D 600 was designed 3.8 mm x 1.2 mm in diameter, and the standard of the screw structure was Class M 3.5 x 0.35 (Fig. 2).

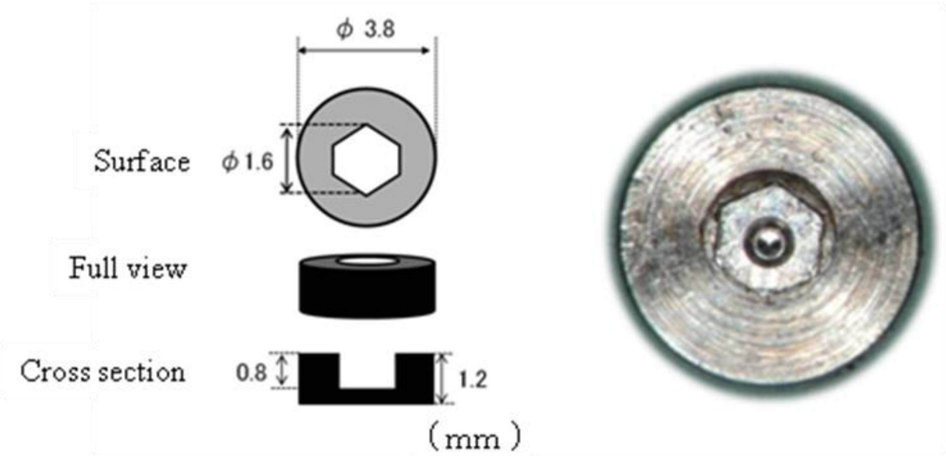

Figure 2. Prototype implant keeper

2) Experimental abutment

An abutment was designed to fit a prototype implant keeper. The size of a experimental abutment was 4.4 mm x 3.7 mm in diameter.

2.Methods

The lower plate simulating the environment that the prototype implant was placed into the bone, and the upper plate simulating an overdenture on the top were fabricated. The accelerated study was performed by applying repeated loads on the upper and lower plates to measure loosening of a keeper.

1) Lower plate

A square plate was fabricated using base resin (ACRON MC, GC, Tokyo), and 25 abutments were fixed concentrically from the center of the place using self-curing resin (UNIFAST, GC, Tokyo). The upper surfaces of abutments were adjusted to be on the same surface. Implant keepers were fixed on the abutments secured on the plate using a torque gauge (FTD50CN2-S, TOHNICHI, Tokyo). Torque value was changed to 1, 2, 3, 4, 5, 10, 15, 20, and 25 N, and 5 implant keepers were fixed at each torque value (Fig. 3 and 4).

Figure 3. Torque gauge

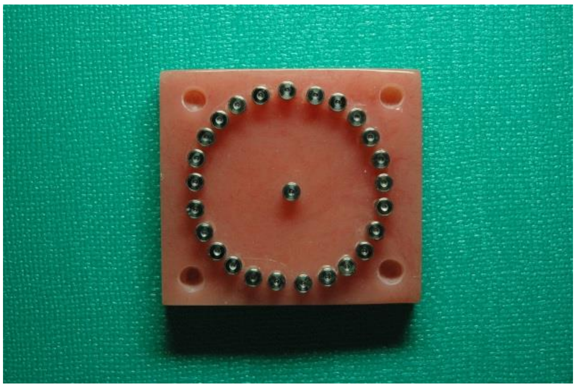

Figure 4. Lower plate

2) Upper plate

Although magnetic attachments were supposed to be incorporated into the upper plate reproducing an overdenture, keepers (GIGAUSS D600, GC, Tokyo) were conveniently used instead of magnetic structure in the present study. The upper plate was fixed to the lower plate to make a pair using the UNIFAST (Fig. 5).

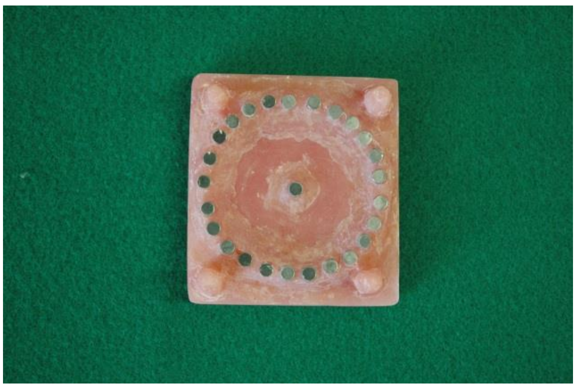

Figure 5. Upper plate

3) Repeated loads

(1) Loading

The upper plate was placed over the lower plate, and the load was applied to the upper plate so that repeated load was applied indirectly to the implant keeper. Only a keeper of the upper plate assuming a magnetic assembly was set to be in contact with an implant keeper fixed in the lower plate, followed by load application (Fig. 6, 7).

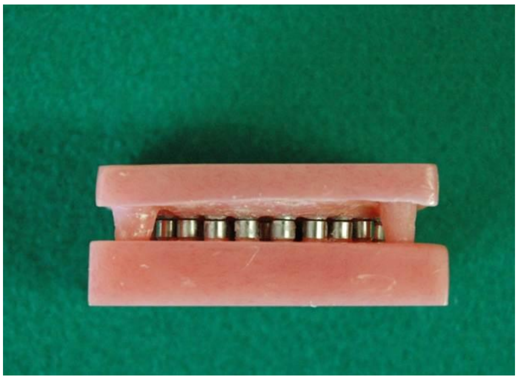

Figure 6.The upper plate was placed over the lower plate

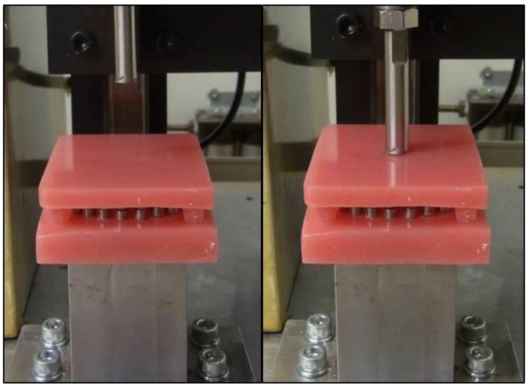

Figure 7. Repetition load

(2) Loading condition

A tap tester devised in our department was used for the load test (Fig. 8). A 20 kgf load was repeatedly applied 500,000 times at a cycle of 0.8 seconds.

Figure 8.Tap tester devised in our department

4) Measurement method

The torque values for fixing an implant keeper and for removing it after repeated loading were compared. The difference of the torque values for fixation and removal of an implant keeper was calculated, and it was set as the loosening value of a screw.

Results

Although there was no detachment of a keeper from the abutment after repeated loading of 500,000 times, loosening of a screw was confirmed in all samples. The torque value was decreased by 70.0% at 1N fixed torque value, 18.0% at 2N, 11.4% at 3N, 5.5% at 4N, 3.6% at 5.10N, 6.1% at 15N torque value before loading, 6.4% at 20N, and 9.8% at 25N (Table. 1).

Table.1 Loosening of a keeper after the load test

before loading	after loading		
torque value (N)	torque value (N)	standard deviation	decreasing rate (%)
1	0.30	0.20	70
2	1.6	0.15	18
3	2.7	0.17	11
4	3.8	0.15	5.5
5	4.8	0.42	3.6
10	9.6	0.52	3.6
15	14.0	0.82	6.1
20	18.0	0.70	6.4
25	22.0	0.48	9.8

Discussion

It is said that a screw has a proper torque. The proper torque value is a value when a screw is tightened with small rate of decrease in the torque value. The results of the present study showed that the rate of decrease in the torque value was the smallest when a keeper was fixed with 5 – 10 N torque value, suggesting that the proper torque value was around 5 – 10 N.

Some keepers fixed with over 20 N torque values showed surface bounce. It is considered that the margin of a screw hole bounced during fixation of a keeper to an abutment with the large torque value due to soft magnetic stainless-steel keeper. The adsorption face is distorted, resulting in a decrease in magnetic attraction of magnetic attachment.

The results of the present study suggested that the proper torque value to fix a prototype implant keeper with fine screw structure of M 3.5 x 0.35 using hexagonal screw hole (1.3 mm in diameter and 0.8 mm in depth) is 5 – 10 N.

Conclusion

Repeated load was applied to a prototype implant keeper 500,000 times, which is equivalent to the number of chewing strokes per year, to investigate loosening of a keeper screw, and the following results were obtained:

1. 500,000 times repeated loading caused loosening of a screw in all samples despite the size of the torque value.
2. The proper torque value to fix a prototype implant keeper was 5.10 N.

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