FATIGUE RESISTANCE OF DENTAL IMPLANTS TREATED WITH LASER METHOD

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Statement of problem. Many surface processing methods of dental implant have been developed, the laser processing is one of them.

Purpose. This study was to investigate in vitro the fatigue resistance of implants treated with laser method(CSM implant, CSM Company, Daegu, Korea).

Material and methods. Fatigue tests of 23 laser treated CSM implant(CSM Company, Daegu, Korea) were conducted using Instron 8871 (Load cell, 5 kN, Instron Co., England), according to ISO 14801 (2003),

Results. From 300 N, each specimens were not fractured and withstood until more than 5,000,000 cycle.

Conclusion. Within the limits of this in vitro study, implants treated with laser method (CSM implant, CSM Company, Daegu, Korea) have had enough rigidity and fatigue resistance to use clinically with reliance.

Key Words
Fatigue resistance, Laser treated CSM implant, ISO 14801 (2003), Clinically, Reliance

The use of osseointegrated dental implants had become a successful procedure for the treatment of complete,[1] partial[2] edentulism, and single-tooth replacements in both the anterior and posterior regions of the mouth.[3-5]

A stable anchoring is the primary goal of implant dentistry. Osseointegration is defined as the direct connection from implant to living remodelling bone without any soft tissue component between implant and bone on the light microscopic level.[6] A rapid osseointegration is associated with improved secondary stability and, thus, with a favorable prognosis for long-term success of the implant.[7,8] Initial stability has to be achieved by reduction of micromotion.[9]

In order to reduce micromotion initially, and to improve osseointegration later on, many variants in surface geometry of the implant have been developed.[10-12] It is well known that surface geometry determines the interaction s of proteins and cells with the implant surface,[13,14] and that increased surface roughness is associated with better cell adherence, higher bone-implant contact(BIC), and improved biomechanical interaction.[6,15-19]

However the sintering process can lead to brittleness and reduced fatigue strength.[20] The laser processing is a new method of treating implant surfaces to produce a high degree of purity with enough roughness for good osseointergration.[21]

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Fatigue is defined as progressive crack propagation resulting in catastrophic fracture under repeated loading below yield stress.[22] In the implant manufacturers, fatigue may be partially or completely responsible for the mechanical failures. So, the individual implant manufacturers attempted to avoid mechanical failures by increasing the implant diameter, modifying the screw joint design, and/or changing the material.

The purpose of this study was to investigate in vitro the fatigue resistance of implants treated with laser method(CSM implant, CSM Company, Daegu, Korea).

MATERIAL AND METHODS

Implant samples

A total of 23 screw shaped, commercially pure titanium implants with a length of 10 mm, a diameter of 3.75 mm were used in present study. They treated with laser method (CSM implant, CSM Company, Daegu, Korea).

To insure that the laser treatment did not severely change the shape of the screws, Nikon Measurescope 10 (Nikon, Tokyo, Japan) equipped with a digital counter was used to measure the outer diameter of five randomly chosen implants from the each groups.

Load-displacement test

First to establish the optimal load for the fatigue,

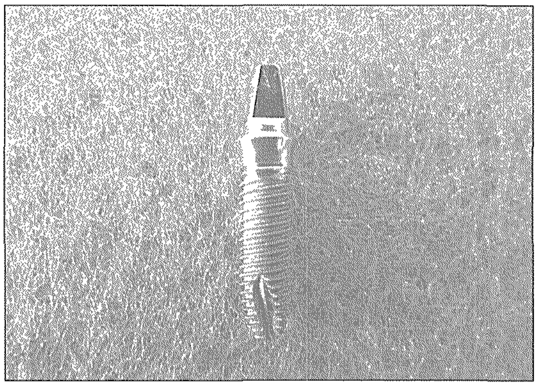


Fig. 1. Implant fixture (CSM implant, CSM Company, Daegu, Korea).

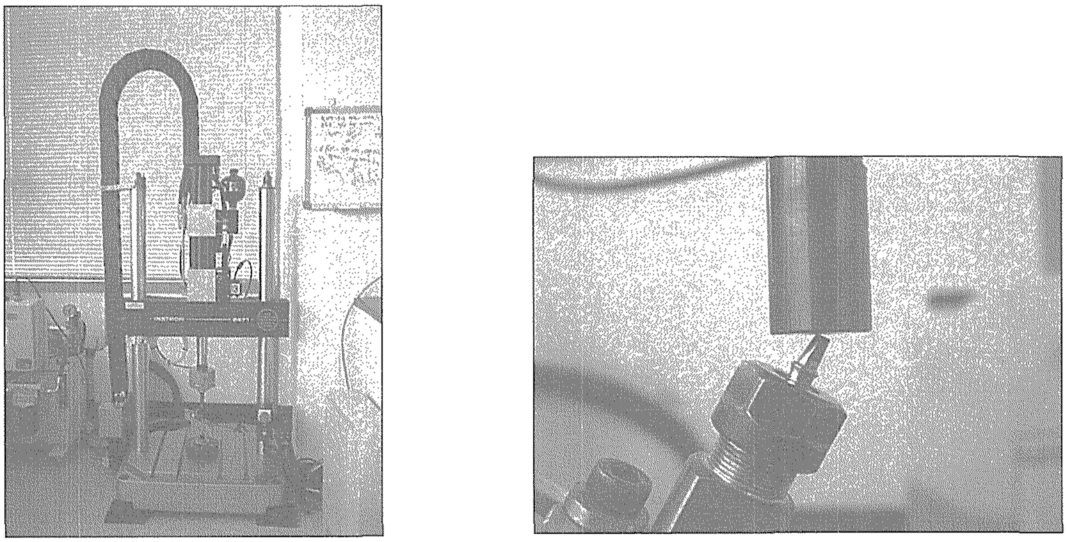


Fig. 2. Fatigue testing machine and jig (Instron 8871, Instron Co., England).

static compressive strength was measured using the specimen holding jig proposed by the method of fatigue testing (ISO 14801:2003). The specimen shall be clamped such that its axis makes a 30° angle with the loading direction of the testing machine and the distance from the centre of the hemisphere to its clamping plane is defined 11 mm. Five specimens were randomly selected and tested at speed of 1.0 mm/min using a universal testing machine (Instron 4200, Instron Co., USA). Maximum load value on the load-displacement curve had been set for static compressive strength.

Fatigue test

Fatigue tests were conducted according to ISO 14801 (2003). Instron 8871 (Load cell, 5 kN, Instron Co., England) was used for this experiment as fatigue testing machine. The specimens should be clamped such that was identical to that described above. A cyclic, sinusoidal loading program was applied at frequency ≦ 14Hz. The enviornment should be kept at room temperature during the testing. It generated a load-cycle diagram by testing specimens at a series of loads until a lower limit is reached at which at least three specimens survive and none fail in 5×10^6 cycles. It began with about 80% of the mean static compressive strength. Thereafter the test had took over again at 80% of the former load. Fatigue limit was defined maximum load at which at least three specimens should reach 5×10^6 cycles with no failures.

RESULTS

Table I, Fig. 3 shows the results of static compressive test and load-displacement curve, respectiuely. Mean value was 1145 N.

The test were begun with 916 N, that is about 80% of the mean static compressive strength(1145 N). Table II shows the results of the fatigue test. From 300 N, that is about 80% of 375 N, each were not fractured and withstood until 6,008,134 cycle, 5,051,600 cycle, 5,009,900 cycle, so that the fatigue limit was revealed at 300 N.

The strength versus number of cycles to failure curve(S-N curve) and the aspect of specimens after the test is shown in Fig. 4, 5, respectively. There was no observed one such a breakage, crack, deformation, and so on at the specimens revealed the fatigue limit.

Table I. Results of static compressive test

Specimen No.	Maximum compressive strength(N)
Specimen 1	1064
Specimen 2	1138
Specimen 3	1150
Specimen 4	1129
Specimen 5	1246
Mean±S.D.	1145±65.44

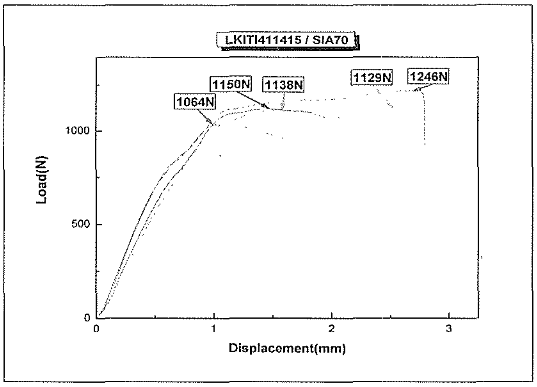


Fig. 3. Load-displacement curve of static compressive test.

Table II. Results of the fatigue test

Load (N)	Failure cycle	
916	Specimen 1	7,500
	Specimen 2	10,513
	Specimen 3	15,600
733	Specimen 1	22,841
	Specimen 2	22,899
	Specimen 3	17,919
586	Specimen 1	93,927
	Specimen 2	57,112
	Specimen 3	59,718
469	Specimen 1	77,614
	Specimen 2	128,202
	Specimen 3	158,561
375	Specimen 1	287,541
	Specimen 2	165,396
	Specimen 3	657,914
300	Specimen 1	6,008,134
	Specimen 2	5,051,600
	Specimen 3	5,009,900

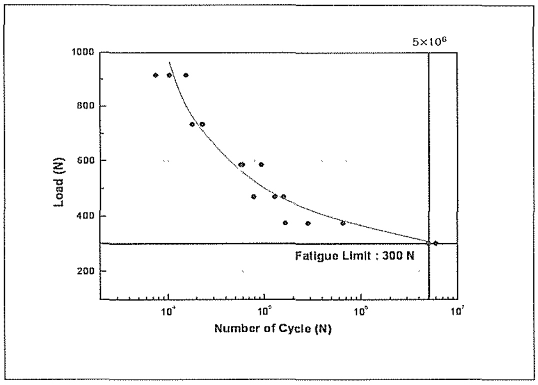
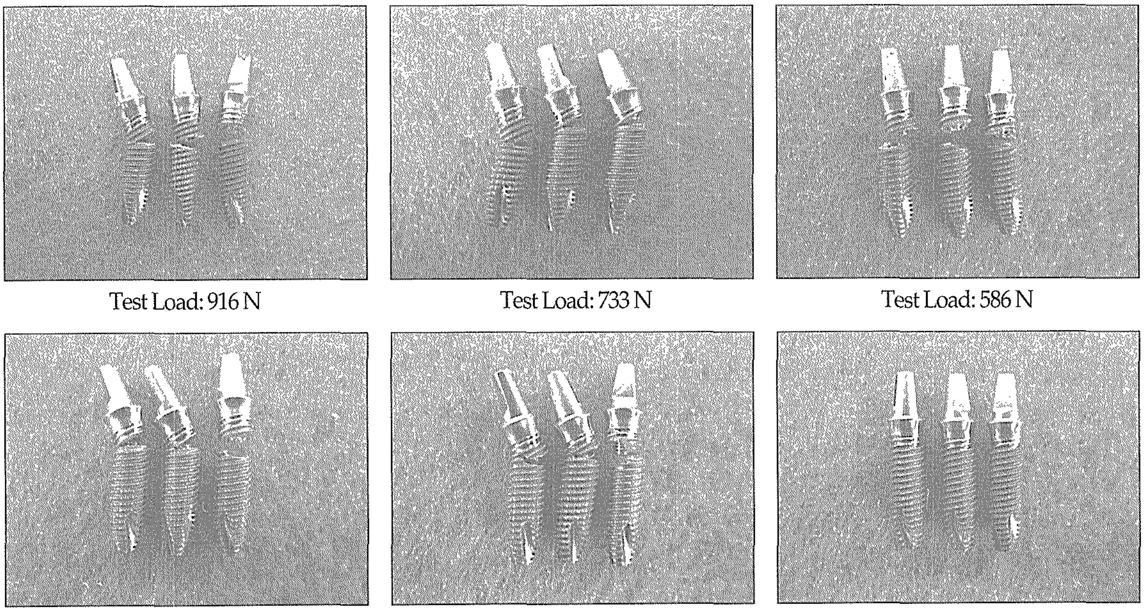


Fig. 4. S-N curve obtained the fatigue test.



Test Load: 916 N   Test Load: 733 N   Test Load: 586 N

Test Load : 469 N   Test Load : 375 N   Test Load : 300 N

Fig. 5. Aspect of specimens after the fatigue test.

DISCUSSION

Several studies have reported that the rough implant surfaces of varying topography generally demonstrate increased bone apposition and higher removal torque when compared to machined surface.[23-26] Using the transcortical model, Thomas et al.[27] found that implants with a roughened surface had a great interface strength and higher surface coverage by bone than smooth implants. Buser et al.[28] found that increasing implant surface roughness generally correlated with increased surface coverage by bone. It is assumed that rough surface is one of the important factors in success of dental implants.

Laser treatment of metal implants may be a very interesting technology for the structuring of implant surfaces. Bone ingrowth into pores causes interlocking of the surrounding bone tissue with the implant, and may result in improved biomechanical stability and higher resistance to fatigue loading.[29-31]

Cho et al.[32] reported that the laser treated implant achieved higher removal torque values compared to the machined control group. The greater removal torque values may be related primarily to the higher bone to implant contact.[33]

It has been reported that roughening titanium alloy may decrease the fatigue strength.[34]

Fatigue strength is the stress at which a material fails under repeated loads.

The fatigue strength of implants treated with laser method (CSM implant, CSM Company, Daegu, Korea) were examined. It revealed the implants to an fatigue limit of 300 N. This value is enough to allow clinical usage of them. And this results indicated that laser treatment would not adversely affect the fatigue strength of the dental implant.

In present study, specimens were exposed 8mm above the face of the test jig to simulate 3 mm bone resorption. Moreover, the fixed cycling frequency of 14Hz used was higher than the reported chewing rate(1 to 2 Hz).[35] It might provide a worst case to the test.

Finally, there might be need for prospective and retrospective reports of short and long-term to evaluate and verify the success and the accompanied problems for CSM implant systems.

CONCLUSION

Within the limits of this in vitro study, the following conclusion can be drawn : Implants treated with laser method (CSM implant, CSM Company, Daegu, Korea) have shown adequate rigidity and resistance to fatigue, so that the clinical use of them may be reliable. Also, it may be concluded that laser treatment would not adversely affect the fatigue strength of the dental implant.

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