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The Study of Fatigue of Implanting in Different Fastening Method

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Abstract

4 kinds of implants with different fastening methods with the fixture of equally selected diameter 3.6 mm, length 15 mm and abutment of diameter5.0mm, length 5.7mm and fastened and fixed with the force of 30N·cm and then fatigue test was carried out by using tensile and compression tester (858 Bionix, MTS, USA). According to the fatigue test results, all 4 types of implants met the fatigue test standard of withstanding the load of 5 × 10^6 Cycles in more than 250N, dental implant testing criteria of Korean Food & Drug Administration medical device standard. 4 kinds of implant fixture and abutment fatigue test results with different fastening methods showed statistically significant differences ($p<0.001$).

Keywords: *Dental Implant, Fatigue Limit, Implant Fixture and Abutment*

1. Introduction

Dental implant has been applied to patients as a variety of prosthetic treatment methods in clinical trials and the demand for the prosthesis using implant is increasing around the world due to increasing income level and patients' needs for higher medical services *etc.* [1]. The previous study of Cho and Kim [2] shows that 76.9% of patients want the implant prosthesis when extracting a tooth and reported that 91.5% answered implant is necessary after extraction. The prosthetic treatment using early implant started with prosthetic treatment of edentulous patients [3] and is currently used as the prosthetic treatment method of one or two single teeth [4, 5].

Thanks to the development of the implant manufacturing technology so far, more precise products than in the past are variously distributed to clinical trials and the patient's pain and discomfort were reduced because the development of implant surgery equipment and technology shortened surgery time and enabled treatment without secondary surgery and also reduced the number of dental visits of implant surgery patients. However, the implant treatment method is a prosthetic treatment method with limitations in the application of implant prosthetics depending on the oral condition of the patient.

As failure factors of implant prosthetics, loosening of screws and fracture problems when applying repeated load to implant have been reported [6, 7] and these implant screw loosening and facture may occur by inaccurate processing of implant fixture, abutment, screw and low tightening fixation, deformation of the implant fastening part by excessive tightening force, repeated occlusal loading, adverse occlusion, fit of inaccurate prosthesis *etc.* [8-11].

Generally, fracture strength of implant refers to the force when fractured instantly by applying the load of more than yield strength to implant, and implants currently used in the clinical trials has strength that can fully withstand occlusal pressure occurring in the mouth [12]. Fatigue fracture is the fracture generated by repeated stress lower yield strength [13-16]. In long-term clinical study reports of implant prosthesis placed in the

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patient's mouth, implant prosthetics placed in maxillary (upper jaw) showed a stability of more than 95% in the period between 5 -10 years but showed a stability of 92% in more than 15 years, reporting that the fracture rate is increasing in the long term [3]. This fracture of implant may be regarded as a problem likely to happen sufficiently when exposed for a long time by continuous load.

Studies related to fatigue fracture of implant include studies of testing fatigue fracture by making the prostheses with UCLA gold abutment in external hexagon connection Implant Fixture of several manufacturing companies [17], fatigue fracture studies carried out by making a model equipped with four different abutments in Internal hexagon connection Implant Fixture(GS Ⅱ Fixture, Osstem, Korea) of submerged type with morse taper of 11° [18] and fatigue fracture studies using implant of One body o-ring type [19]. However, there are only a few fatigue fracture studies targeting implant of the same size by fastening method of implant.

This study was carried out to conduct a test according to performance stability evaluation test manual of dental implant of Food & Drug Administration and implant dynamic fatigue test criteria of ISO 14801 [13] targeting 4 kinds of implant fixtures and abutment with the same diameter and length and different fastening method among commercially available implants in Korea and its purpose is to investigate the level of fatigue fracture of implants by fastening method and examine the difference in the degree of fatigue fracture of implant depending on the fastening method and to use the results as oral health data.

2. Research Methods

2.1. Test Methods

This study targeted a total of 4 kinds of Implant Fixtures and Implant abutments such as Internal octagon connection Implant(YI Implant, Yesbiotech, KOREA) with morse taper angle of 8°in the fastening part between fixture and abutment, Internal hexagon connection Implant(A&B Implant, A&B Biomedi, KOREA) of submerged type with morse taper shape of 1.5°, External hexagon connection Implant(YE Implant, Yesbiotech, KOREA) and Internal hexagon connection Implant(YS Implant, Yesbiotech, KOREA) of submerged type with morse taper of 11°.

The diameter and length of each implant fixture were selected to be 3.6 mm and 15 mm, respectively and diameter and length of Implant abutment to be 5.0 mm, and 5.7 mm, respectively and were united in the same size as shear compression test study of Park, *et al.*, [12] (Table 1).

The test was based on implant dynamic fatigue test criteria of ISO 14801 and a total of 4 kinds of implant fixtures and implant abutments were tightened and fixed with a force of 30N ·cm with fixing screws by using Electric Torque Meter (MGT50E, MARK-10, USA) and fatigue fracture test was carried out in the range of room temperature 20 ± 5°, humidity 30 ± 10 %.

The fatigue fracture test of implant by each fastening method used tensile and compression tester(858 Bionix, MTS, USA) and average shear compression strength of implant was based on the results of average shear compression strength of Park, *et al.*, [12]'s previous studies on implant and early load started with average shear strength 80 % load and load cycle of 14Hz of previous studies findings and the test was carried out by lowering fatigue load by 20% when fatigue fracture of each implant test specimen occurred.

For precise measurement of implant fatigue fracture test by each fastening method, fatigue fracture of 2 specimens was tested in each load and the mean value was used by measuring fatigue fracture of 5 specimens at the point where final fatigue facture occurred. By each fastening method, the test was carried out until 5 implant specimens withstand 5×10^6 Cycles.

Table 1. Implant Specimen Size of 4 Kinds (mm)

Implant type		Ø	Length
YI Implant	Fixture	3.6	15
	Abutment	5.0	5.7
A&B Implant	Fixture	3.6	15
	Abutment	5.0	5.7
YS Implant	Fixture	3.6	15
	Abutment	5.0	5.7
YE Implant	Fixture	3.6	15
	Abutment	5.0	5.7

2.2. Analysis of Test Results

The statistics program SPSS ver. 18.0 was used for processing analysis of the fatigue fracture test data of 4 kinds of implants measured in this study and fatigue fracture values of implant by each fastening method were displayed by using S-N curve graph.

ANOVA batch analysis was used to compare the final figures of fatigue fracture of implant by each fastening method and post-verification was carried out by using TuKey HSD for post-verification.

3. Results

The fatigue fracture of internal octagon connection implant with morse taper angle of 8°was measured and as a result, in the load of 967 N and load cycle of 14Hz, 2 implant specimens showed fatigue fracture in 32 cycles and 27 cycles, respectively and in the load of 774 N and load cycle of 14Hz, 2 implant specimens showed fatigue fracture in 46 cycles and 44 cycles, respectively and in the load of 619 N and load cycle of 14Hz, 2 implant specimens in 7,352 cycles and5,941 cycles, respectively and in the load of 495 N and load cycle of 14Hz, 2 implant specimens in 25,016 cycles and 22,487 cycles, respectively. In the load of 396 N 의 and load cycle of 14Hz, 5 implant specimens showed fatigue fracture in the order of 193,825 cycles, 163,745 cycles, 134,835 cycles, 83,414 cycles, 78,521 cycles. In the load of 317 N and load cycle of 14Hz, all 5 implant specimens did not show fatigue fracture by repeated load of 5×10^6 cycles (Table 2), (Figure 1).

Table 2. Yi implant Fatigue Limit Test (n=18)

Load(N)	Cycles
967 N	27
	32
774 N	46
	44
619 N	7,352
	5,941
495 N	22,487
	25,016
396 N	134,835
	83,414
	78,521
	193,825
	163,745

317 N	5,000,000
	5,000,000
	5,000,000
	5,000,000
	5,000,000
Fatigue limit	317 N

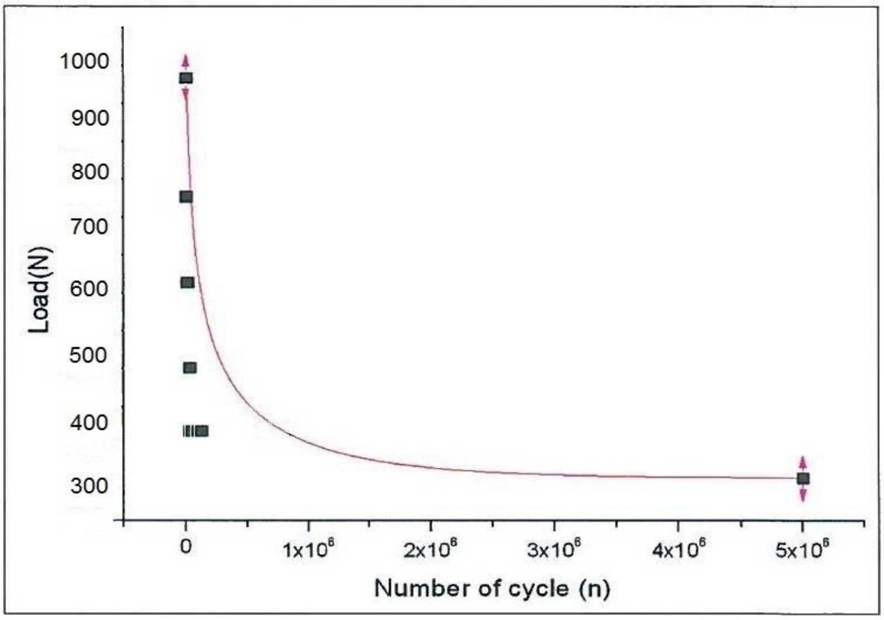

Figure 1. S-n Curve of Yi Implant

The fatigue fracture of internal hexagon connection implant of submerged type with the morse taper shape of 1.5°was measured and as a result, in the load of 785 N and load cycle of 14Hz, 2 implant specimens showed fatigue fracture in 57 cycles and 43 cycles, respectively and in the load of 628 N and load cycle of 14Hz, 2 implant specimens in 360 cycles and 157 cycles, respectively and in the load of 502 N and load cycle of 14Hz, 2 implant specimens in 19,571 cycles and 5,423 cycles, respectively. In the load of 402 N and load cycle of 14Hz, 5 implant specimens showed fatigue fracture in the order of 892,676 cycle and748,349 cycles, 627,485 cycles, 534,376 cycles, 495,240 cycles. In the load of 322 N and load cycle of 14Hz, all the 5 implant specimens did not show fatigue fracture by repeated load of 5×10^6 cycles (Table 3), (Fig 2).

The fatigue fracture of external hexagon connection implant was measured and as a result, in the load of 913 N and load cycle of 14Hz, 2 implant specimens showed 14Hz in 423 cycles and 47 cycles, respectively and in the load of 730 N and load cycle of 14Hz, 2 implant specimens in 10,916 cycles and 6,538 cycles, respectively and in the load of 584 N and load cycle of 14Hz, 2 implant specimens showed fatigue fracture in 15,916 cycles and 9,905 cycles, respectively. In the load of 467 N and load cycle of 14Hz, 5 implant specimens showed fatigue fracture in the order of 57,884 cycles, 49,024 cycles and 48,754 cycles, 38,957 cycles, 32,141 cycles. In the load of 374 N and load cycle of 14Hz, all the 5 implant specimens did not show fatigue fracture by repeated load of 5×10^6 cycles (Table 4), (Figure 3).

Table 3. A&B Implant Fatigue Limit Test (N=16)

Load(N)	Cycles
785 N	57
	43
628 N	360
	157
502 N	5,423
	19,571
402 N	495,240
	627,485
	748,349
	534,376
	892,676
322 N	5,000,000
	5,000,000
	5,000,000
	5,000,000
	5,000,000
Fatigue limit	322 N

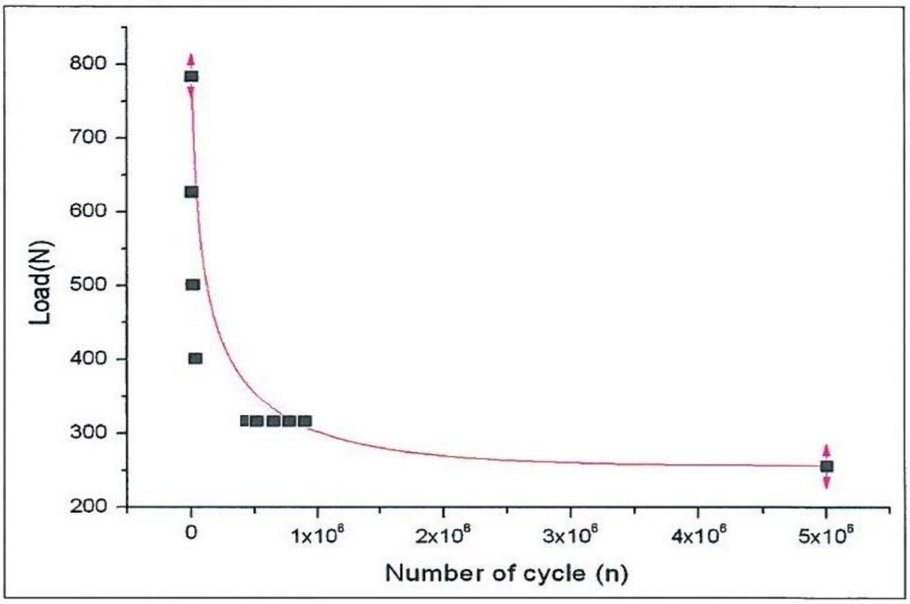

Figure 2. S-N Curve Test of A&B Implant

Table 4. YE Implant Fatigue Limit Test (N=16)

Load(N)	Cycles
913 N	423
	47
730 N	10,916
	6,538
584 N	9,905
	15,916
467 N	49,024
	57,884
	38,957
	48,754

	32,141
374 N	5,000,000
	5,000,000
	5,000,000
	5,000,000
	5,000,000
Fatigue limit	374 N

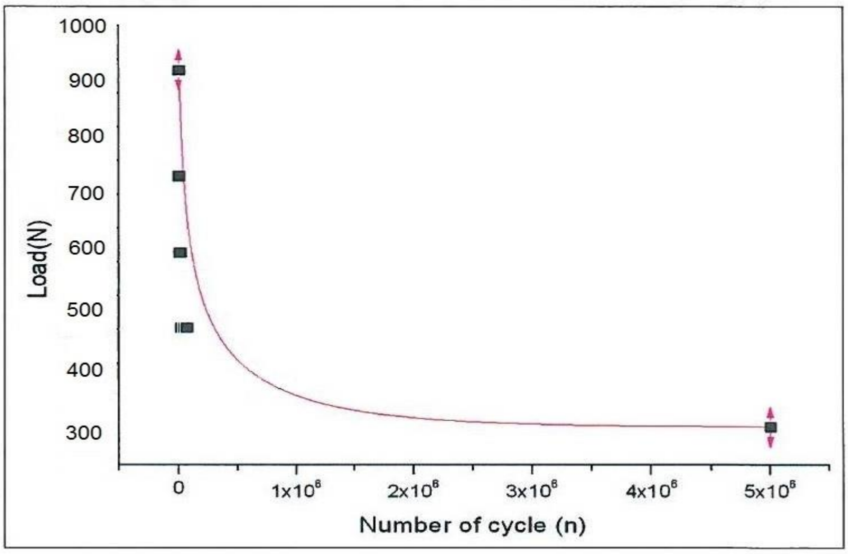

Figure 3. S-N Curve Test of YE Implant

The fatigue fracture of internal hexagon connection implant of submerged type with morse taper of 11°in the fastening part was measured, and as a result, in the load of 494 N and load cycle of 14Hz, 2 implant specimens showed fatigue fracture in 6,342 cycles and 4,941 cycles, respectively, and in the load of 395 N and load cycle of 14Hz, 5 implant specimens showed fatigue fracture in the order of 27,358 cycles, 25,719 cycles, 23,096 cycles, 21,425 cycles, 19,454 cycles. In the load of 316 N and load cycle of 14Hz, all the 5 implant specimens did not show fatigue fracture by repeated load of $5{\times}10^6$ cycles (Table 5), (Figure 4).

Table 5. YS Implant Fatigue Limit Test (N=12)

Load(N)	Cycles
494 N	4,941
	6,342
395 N	19,454
	23,096
	21,425
	27,358
	25,719
316 N	5,000,000
	5,000,000
	5,000,000
	5,000,000
	5,000,000
Fatigue limit	316 N

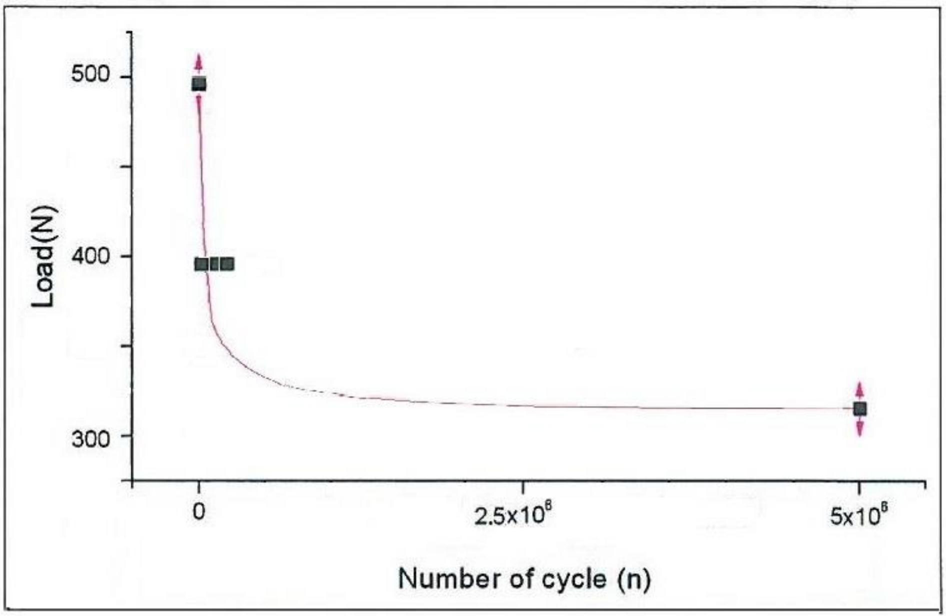

Figure 4. S-N Curve Test of YS Implant

According to the results of the final fatigue fracture test of a total of 4 kinds with different fastening methods, in the load of 402N and load cycle of 14Hz, internal hexagon connection implant of submerged type with the morse taper shape of 1.5°showed the highest final fatigue fracture cycles in average 659625.20 cycles and in the load of 396N and load cycle of 14Hz, internal octagon connection implant with the morse taper angle of 8°in average 130868.00 cycles and in the load of 467N and load cycle of 14Hz, external hexagon connection implant in 44462.00 cycles and in the load of 395N and load cycle of 14Hz, Internal hexagon connection Implant of submerged type with morse taper of 11°showed the final fatigue fracture cycles in 23116.20 cycles. The final fatigue fracture cycles of Internal hexagon connection Implant of submerged type with the morse taper shape of 1.5° showed statistically significant differences from other 3 kinds of implants (Table 6).

Table 6. Comparison of Final Fatigue Fracture Test of 4 Kinds of Implants by Fastening Method (N=20)

Implant type	N	Mean	SD	*F*	p-value
YI Implant(396N)	5	130868.00[a]	50130.601	61.975	0.000
A&B Implant(402N)	5	659625.20[b]	162732.477		
YE Implant(467N)	5	44462.00[a]	10469.336		
YS Implant(395N)	5	23116.20[a]	3396.558		

TuKey HSD:[a,b].
Within mean ± SD values column, values with different letter were significantly different between the groups

4. Discussion

Due to its advantage for the prosthetic treatment without damaging surrounding teeth, the demand for implant prosthetics is increasing in clinical dentistry. Despite the high clinical success rate of several dental implants, however, the problem for fatigue fracture of implant has been studied and reported [3, 14-18]. Several studies related to implant fatigue fracture have been reported but most fatigue fracture studies compared manufacturing companies targeting implant fixture of the same fastening method [17] or some studies compared abutments with different production methods with implant fixture of the same manufacturing company [18]. However, no fatigue fracture studies targeted implant fixture and abutment with the same diameter and length and different fastening methods.

In order to investigate the difference in fatigue fracture depending on the difference of implant fastening methods, we carried out a study targeting implant with the same size.

It was reported that the causes of implant fracture, the diameter of fixture greatly affects fracture strength of implant in the anterior part and fracture strength increases dramatically as the diameter gets larger [20]. In the previous fatigue fracture study of Park and Cho [17], the highest group showed fatigue fracture in average 105,371 Cycle, higher than average ,462 Cycle, the final fatigue fracture of External hexagon connection Implant, the same fastening method of this study. The fatigue fracture test results are considered to have showed a difference because the fatigue fracture study of Park and Cho [17] is a fatigue fracture test with the load from maximum 600N to minimum 60N in fixture of diameter 4.0mm, length 10.0mm and the diameter is thicker than 0.3mm of fixture tested in this study.

The study was carried out by using implants with the smallest implant fixture diameter among implant diameters used in clinical trials. Given the results of previous studies that fracture strength increases as the diameter gets larger [20], fatigue strength of fatigue strength of wide diameter is determined to be higher than the results of this study.

In the study of Kim and Cho [18], targeting Internal hexagon connection Implant of submerged type with morse taper of 11°with implant fixture diameter 4.5mm, length 10mm, fatigue fracture test results were shown from lowest group average 6,538 cycle to higher group average 30,560 cycle depending on the types of abutment and showed a lot of difference from 23,116 cycle of Internal hexagon connection Implant group of submerged type, the same fastening method used in this study.

This is determined to be difference by material differences of diameter and abutment of implant and fixture. Based on the report of previous studies that fracture occurs by inaccurate processing of implant fixture and clamping screws [8], the difference in fatigue fracture cycle of each implant of fastening part in this study is considered to be caused by tolerance with the fastening part of clamping screws of implants.

This study was based on average shear compression load of previous studies on shear compression load [12] and average shear compression load 80% was based on ISO 14801 and the test was carried out by lowering fatigue load by 20% when fatigue fracture of implant test specimen occurred and the strength was obtained until withstanding final fatigue fracture strength and 5×10^6 Cycles and the differences were compared by fastening method.

The implant prosthetics has a problem that when exposed for a long time by continuous load after mounted in the mouth, implant is likely to be fractured [3]. However, all four types of implant used in this study were found to withstand the load of 5×10^6 Cycles in the load of more than 316N and show sufficient fatigue fracture strength by meeting all the criteria of withstanding the load of 5×10^6 Cycles in the fatigue test of more than 250N of medical equipment standard dental implant of Food & Drug Administration.

5. Conclusions

This study carried out a fatigue fracture test based on implant fatigue test standards of ISO 14801 by targeting 4 kinds of implant with different fastening methods and selecting the same fixture and abutment. In the fatigue test of each implant, the load of 5×10^6 Cycles was investigated to be the final fatigue limit of

Internal hexagon connection Implant of submerged type with submerged type of 11°, Internal octagon connection Implant with morse taper angle of 8°, Internal hexagon connection Implant of submerged type with the morse taper shape of 1.5°and External hexagon connection Implant in 316N, 317N, 322N and 374N, respectively. All implants used in the test were investigated to be higher than 250N, Korean FDA medical device standard dental implant testing criteria fatigue testing standard, fully meeting the criteria.

In the difference of implant final fatigue fracture by fastening method, Internal hexagon connection Implant of submerged type with the morse taper shape of 1.5°showed statistically significant differences from other 3 kinds of implant but it is considered that there was a limitation of the study in conducting a fatigue fracture test based on average shear compression strength results of implant by implant and comparing fatigue fracture differences of 4 kinds of implant.

The fatigue fracture level of implant used in this study is determined to be enough to be used in clinical trials and a variety of research is considered to be needed in the future such as fatigue fracture test by implants under the same load and studies targeting implant of various sizes.

Acknowledgments

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