A COMPARATIVE STUDY OF THE 1-PIECE AND 2-PIECE CONICAL ABUTMENT JOINT : THE STRENGTH AND THE FATIGUE RESISTANCE

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Statement of problem. The performance and maintenance of implant-supported prostheses are primarily dependent upon load transmission both at the bone-to-implant interface and within the implant-abutment-prosthesis complex. The design of the interface between components has been shown to have a profound influence on the stability of screw joints.

Purpose. The Purpose of this study was to compare the strength and the fatigue resistance of 1-piece and 2-piece abutment connected to oral implant, utilizing an internal conical interface.

Material and methods. Twenty Implatium® tapered implants were embedded to the top of the fixture in acrylic resin blocks. Ten Combi®(1-piece) and Dual®(2-piece) abutments of the same dimension were assembled to the implants, respectively. The assembled units were mounted in a testing machine. A load was applied perpendicular to the long axis of the assemblies and the loading points was at the distance of 7mm from the block surface. Half of 1-piece and 2-piece abutment-implant units were tested for the evaluation of the bending strength, and the others were cyclically loaded for the evaluation of the fatigue resistance until plastic deformation occurred. Nonparametric statistical analysis was performed for the results.

Results. Mean plastic and maximum bending moment were 1,900±18Nmm, 3,609±106Nmm for the 1-piece abutment, and 1,250±31Nmm, 2,688±166Nmm for the 2-piece abutment, respectively. Mean cycles and standard deviation when implant-abutment joint showed a first plastic deformation were 238,610±44,891. cycles for the 1-piece abutment and 9,476±3,541 cycles for the 2-piece abutment.

A 1-piece abutment showed significantly higher value than a 2-piece abutment in the first plastic bending moment ($p<.05$), maximum bending moment ($p<.05$) and fatigue strength ($p<.05$).

Conclusion. Both 1-piece and 2-piece conical abutment had high strength and fatigue resistance and this suggests long-term durability without mechanical complication. However, the 1-piece conical abutment was more stable than the 2-piece conical abutment in the strength and the fatique resistance.

Key Words

Conical joint, Interface, Bending strength, Fatigue resistance

Several reports have emphasized the integrity of bone/implant interface and endorsed the long-term effectiveness of osseointegrated technique in the oral cavity.[1-3] The use of osseointegrated dental implants had become a successful procedure for the treatment of complete,[1] partial[4] edentulism, and single-tooth replacements in both the anterior and posterior regions of the mouth.[5-7] One commonly reported mechanical problem that affects single-tooth implant replacements is screw joint instability, specifically, loosening or fracture of the abutment or retaining screws.[5-7]

The etiology of screw joint instability has been identified by Glantz et al.[8], who observed the high bending moments were recorded even when loads were placed close to centric occlusion. This suggests the such moments should be accommodated by the joint design, within the limits of normal masticatory load. In several study, it was shown that the internal conical joint was a significantly more stable joint when compared to an external hexagonal or butt joint.[9,10]

Norton[11] compared the static bending strength between 1-piece and 2-piece Astra Tech® abutments (Astra Tech AB, Mölndahl, Sweden). He concluded the 2-piece abutments did not detract the bending resistance of their 11-degree internal-cone joint. but, 1-piece and 2-piece Astra Tech® abutments were not of the same dimension. Even 2-piece abutments showed significantly higher maximum bending strength. It' s the reverse to the author' s hypothesis.

Khraisat et al.[12] compared the ultimate fatigue resistance of CeraOne® and solid abutments connected to single Branemark® and ITI® implants, respectively. It showed that the fatigue strength of the ITI® implant-abutment complex was significantly better than the Branemark® implant-abutment complex. More recently, a comparison study[13] of the fatigue resistance of solid and SynOcta® abutments connected to single ITI implants was shown that solid abutments possess higher removal torque resistance than synOcta® abutments when connected to synOcta® ITI® implants.

Implatium® tapered implants (Dentium, Seoul, South Korea) (Fig. 1) are submerged-type root-form implants and utilize 11-degree internal conical interface the same as Astra Tech® implants. Combi®(1-piece) and Dual®(2-piece) abutments are made of the same dimension and connected to the fixture for the cement-retained superstructures. But,

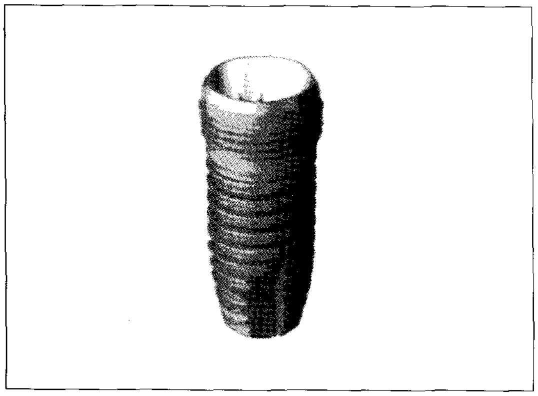

Fig. 1. Implantium® tapered implant (Dentium, Seoul, South Korea).

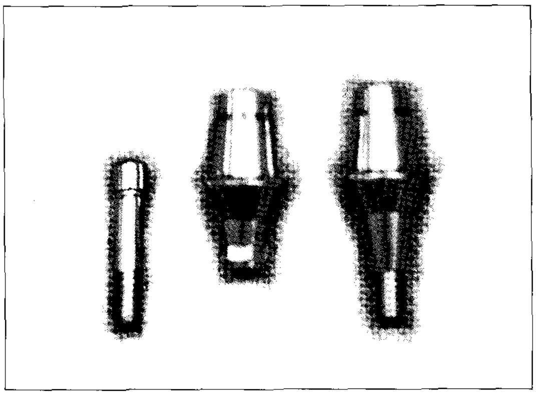

Fig. 2. Dual®(2-piece, left) and Combi® (1-piece, right) abutment.

Dual®(2-piece) abutments with an internal hexagon can resist against rotation(Fig. 2, 3).

The Purpose of this study was to compare the strength and the fatigue resistance of 1-piece and 2-piece Dentium® abutments under lateral static and dynamic loads.

MATERIAL AND METHODS

1. Implant specimens and abutments

This study used 10 assemblies of 2 abutment systems: A solid 1-piece Combi® and a hollow 2-piece Dual® (Dentium, Seoul, South Korea) abutment with an internal hex (Fig. 2). Each of the implant-abutment groups and the corresponding components were delivered from commercially available stock (Table I).

Twenty Implatium® tapered implants were embedded to the top of the fixture in acrylic resin blocks which were prepared by heating the mixture of the powder and the liquid (Ortho-Jet; Lang Dental Mfg. Co., Il, USA) under pressure. These preparations were standardized and utilized with prefabricated mounting jig, corresponding components and PERform Inkovac® pressure/vacuum polymerization unit (Hedent GmbH, Oberursel, Germany).

Ten Combi® (1-piece) abutments and ten Dual® (2-piece) abutments were connected to twenty Implatium® tapered fixtures and tightened to 35Ncm with a torque wrench supplied by manufacturer just before the loading tests.

2. Loading machine and loading approach

Each specimen was firmly mounted in a customized stainless steel jig of a programmable hydraulic loading machine (MTS 858 mini bionix Ⅱ; MTS system Co., Minnesota, USA) (Fig. 4) which controlled by Teststar® Ⅱ (MTS system Co., Minnesota, USA) and programmed with Station manager® (MTS system Co., Minnesota, USA).

The loading was applied perpendicularly to the flat surface of the underlying abutment and the loading point was 7mm distant from the block surface which is maintained by the 7mm thick customized stainless steel bar (Fig. 5).

2.1. Cantilever bending tests

High load tests were run, with increading force and a constant velocity of 0.1mm/sec until such time as the applied load caused a failure of the unit, or maximum load was achieved.

First point of plastic deformation was defined as 0.5mm of permanent displacement, as measured by the Station manager®. This deformaion was sim-

Table I. Components and dimensions of the tested specimens

Components	Dimensions	Material	Article No.	Quantity
Implant	Tapered fixture, ø3.8mm, ø4.0mm N, 14.0mm L	cp-Ti Grade 4	FX3814	20
1-piece Abutment	Combi, ø5.5mm, 2.5mm G/H	cp-Ti Grade 4, TiN coating	CAB5525L	10
2-piece Abutment	Dual, ø5.5mm, 2.5mm G/H	cp-Ti Grade 4, TiN coating	DAB5525HL	10
Abutment screw		cp-Ti Grade 4	ASC2045	10

N : neck, L : length, G/H : gingival height, cp-Ti : commercially pure titanium

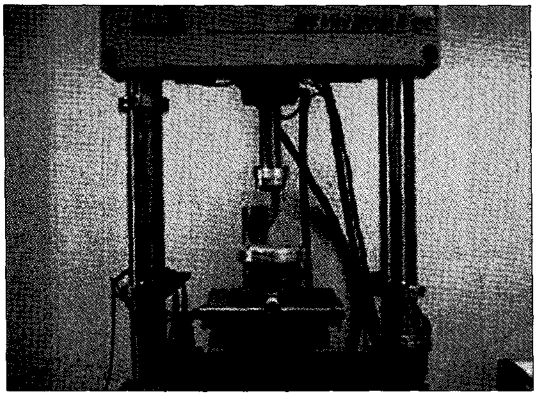

Fig. 4. MTS 858 mini bionix II.

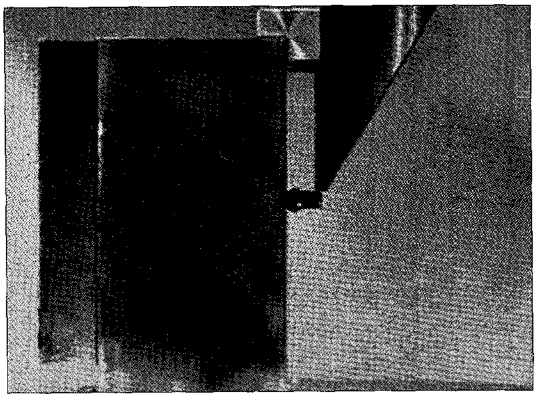

Fig. 5. Loading the specimen.

ilarly determined to be sure of its plastic nature, yet small enough to be of clinical relevance by a previous study.[10,11]

This test was repeated 5 times for each abutment under scrutiny.

2.2. Cyclic loading tests

Cyclic loading of peak loads of 200N and valley loads of 0N with compressive sine wave was applied on the abutments at 14Hz until the first plastic deformation was occurred. This test was also repeated 5 times for each abutment.

3. Statistical analysis

Results were subjected to statistical analysis means by the nonparametric Mann-whitney rank-sum U tests in order to determine the significance of differences between the 2 independent groups. All tests were performed 2-tailed and at the 5% significance level.

RESULTS

Table II gives the results of the cantilever bending test for each unit with the 1-piece and the 2-piece abutments. Point of first plastic deformation and maximum bending moment are recorded in Nmm. Figure 6 and 7 show typical graphs recorded for each abutment design.

The first point at which permanent plastic deformation was recorded for the 1-piece abutment was at a mean moment of 1,900Nmm (load=317N), which compared to a mean moment of 1,250Nmm (load=208N).

A mean maximum bending moment of 3,609Nmm (load=601N) was recorded for the 1-piece abutments compared to a mean maximum bending moment of 2,688Nmm (load=448N) for the 2-piece abutments.

The nonparametric Mann-whitney rank-sum U tests showed a significant difference between the 2 groups (P=0.008, 0.008) in the moment of the first plastic deformation and the maximum bending moment.

In each case the units were dismantled in order to detect where the fracture or large plastic deformation had occurred. For the 1-piece abutment, the point of plastic deformation or critical zone was the conical collar of the fixture, the internal cone of the abutment and the neck of abutment screw, while for the 2-piece abutment, the deformation was noted at the conical collar of the fixture and the neck of the abutment screw (Fig. 8).

Table II. Results from the cantilever bending test

Unit no.	Plastic bending moment (N mm)		Maximum bending moment (N mm)	
	1-piece abutment	2-piece abutment	1-piece abutment	2-piece abutment
1	1923	1469	3533	2768
2	1910	1384	3724	2726
3	1900	1271	3682	2873
4	1876	1078	3467	2430
5	1891	1047	3636	2642
Mean	1900	1250	3609	2688
SD	18	185	106	166
P-value	0.008		0.008	

SD : standard deviation

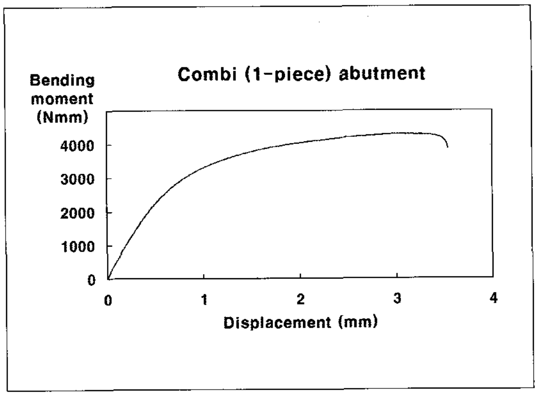

Fig. 6. Cantilever bending performance of a Combi (1-piece) abutment.

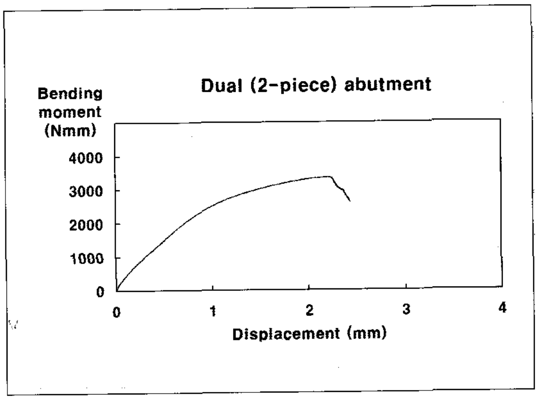

Fig. 7. Cantilever bending performance of a Dual (1-piece) abutment.

Table III shows the result of the cyclic loading tests of the both groups. 1-piece abutment group showed first plastic deformation between 163,950 and 279,125 cycles with a standard deviation of 44,891 cycles, whereas 2-piece abutment group showed first plastic deformation between 5,330 and 13,100 cycles with a standard deviation of 3,542 cycles. The peak/ valley value of the displacement of the abutment maintained constantly just before the plastic deformation and then the peak/ valley value was increased and the amplitude of the displacement wave was amplified in both groups. The nonparametric Mann-whitney rank-sum U test showed a significant difference between the 2 groups (P=0.008).

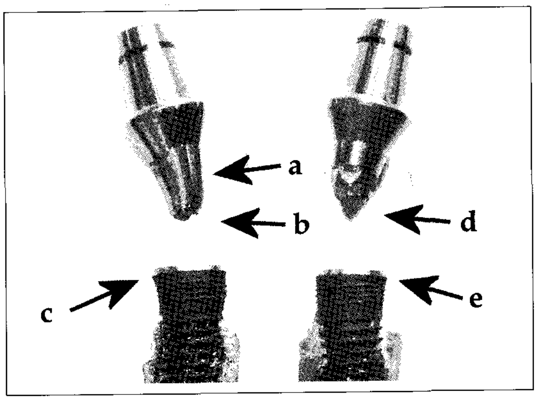

Fig. 8. Critical zone.
Left (Combi, 1-piece) : (a) internal cone of the abutment (b) neck of abutment screw (c) conical collar of the fixture
Right (Dual, 2-piece) : (d) neck of abutment screw (e) conical collar of the fixture.

Table III. Results from the cyclic loading test

Unit no.	Plastic deformation cycles	
	Combi (1-piece) abutment	Dual (2-piece) abutment
1	235,900	5,330
2	163,950	11,850
3	248,125	13,100
4	265,950	6,050
5	279,125	11,050
Mean	238,610	9,476
SD	44,891	3,542
P-value	0.008	

SD : standard deviation

DISCUSSION

There have been few comparison studies about the relative strength and fatigue resistance of 1-piece and 2-piece conical abutment design. In a recent comparative study,[11] 3-point bending strengths of 1-piece and 2-piece Astra Tech® abutments (Astra Tech AB, Mölndahl, Sweden) were recorded with no significant differency in their 11-degree internal-cone joint. Even 2-piece abutments showed significantly higher maximum bending strength. but, 1-piece and 2-piece Astra Tech® abutments were not of the same dimension and the fixtures were screwed into a rigid beam, including conical collar, which might be influence the resistance of conical collar to the bending moment. In this study, the fixtures were embedded in acrylic resin block, which might be influence less than the rigid beam.

Recently, another comparison study[13] of the fatigue resistance of solid and SynOcta® abutments connected to single ITI implants was shown that solid abutments possess higher removal torque resistance than synOcta® abutments when connected to synOcta® ITI® implants, which is corresponded to this study. The period of the steady peak/valley value in the displacement wave might be the time of losing the preload and the friction.

In this study, cyclic loading of peak loads of 200N and valley loads of 0N with compressive sine wave was applied on the abutments. The peak load of 200 N was equivalent to the lateral component of 400 N vertical force on a 20-degree cusp inclination to the implant longitudinal axis. 400 N vertical force was the somewhat higher value than the average one of maximal posterior occlusal force for fixed prosthesis supported by implant.[14] In a pilot study of this study, cyclic loading of 150 N peak loads of 5,000,000 cycles at 14Hz was performed in both 1-piece and 2-piece groups, but no plastic deformation was observed through the whole cycles. Therefore higher loading test was set up to compare the fatigue resistance between the 1-piece and 2-piece abutment.

The critical zone was the conical collar of the fixture, the internal cone of the abutment and the neck of abutment screw for the 1-piece abutment, while for the 2-piece abutment, the deformation was observed at the conical collar of the fixture and the neck of the abutment screw. The inspection of the critical zones indicates that in 1-piece group 3 parts resist the bending moment, in the case of 2-piece abutment only 2 parts resist. Therefore 1-

piece group could show better resistance to the bending moment.

CONCLUSION

Within the limitation of this study, the following conclusion were drawn:

1. Both 1-piece and 2-piece conical abutment have high strength and fatigue resistance and thus function for years without mechanical complication.
2. The 1-piece conical abutment joint shows higher strength than the 2-piece conical abutment joint.
3. The 1-piece conical abutment joint displays higher fatigue resistance than the 2-piece conical abutment joint.

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