ISSN 2765-3633
Vol. 16 No. 1, November 2024
The Journal of Korean Academy of Osseointegration 2024, 16(1) 8-20

Biomechanical comparison of 3D Finite Elements between umbrella type dental implants and conventional type dental implants, and their stability difference in animal experiment

Sung Yul Ahn[1], Suk In Choi[2], Sung Chul Bok[3], Joon Woo Park[4], Dong Ju Choi[5]

[1]Department of Civil Engineering, The University of Seoul, Seoul, [2]Department of Dentistry, Hallym University College of Medicine, Seoul, [3]Snow Dental Clinic, Seoul, [4]Jun Plant Dental Clinic, Seoul, [5]Lifedental Clinic Yangpyeong, Yangpyeong, Korea

Problems during tooth implantation include failure of initial fixation, loss of alveolar bone, and peri-implantitis. Various methods have been proposed to solve these problems, including changing the structure of the implant neck of dental implants ($\phi = 3.3$ mm, L = 10 mm, Neobiotech co. Seoul Korea). We formed an umbrella type structure in the implant neck with the dimension of 0.1 mm, 0.3 mm, 0.5 mm, 0.7 mm, 1.0 mm, investigated its biomechanical significance, and also examined if it would be practically helpful in osteogenesis *in vivo*. For the experiments, we made a finite element model with reference to CT images of patients, in order to compare forces applied to the actual alveolar bone. We produced a model tilted by 10°, similar to actual implants in the mouth, to which we applied 300 Ncm vertical forces in the mouth, and this force divided into vertical force, lateral force, and oblique force. For each of these, we measured principal stress, equivalent stress, lateral displacement, and vertical displacement. For the animal experiment, an implant (Neo-biotech, Korea) with dimensions of 3.3 mm in diameter and 10 mm in length was used in rabbit tibia, and for the experimental group, implants from the same manufacturer were modified with umbrella shapes at the top. The top parts of the modified implants were placed 3 mm above from the superior aspect of the alveolar bone in implantation. Samples were collected after 8 weeks to measure bone growth and removal torque. For the umbrella type implant, there was a decrease in stress transfer of vertical force, lateral force, and oblique force to peri-implant bone as umbrella width increased, while lateral displacement caused by lateral forces and settlement caused by vertical forces also decreased. In the animal experiment, the umbrella type implant resulted in the formation of more alveolar bone, and had a higher removal torque. In conclusion, the umbrella type implant was found to have superior biomechanical properties and osteogenesis. However, further studies are required to investigate whether it is more effective compared to existing implants when it is used clinically. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2024;16(1):8-20)**

Key words: Umbrella type implant, Biomechanically stable, Safe

INTRODUCTION

Implants have been used for a long time to restore lost teeth, and in arriving at their present state, they have undergone a vast number of advances. However, when bone quality is poor, initial fixation of implants may be unstable, leading to various problems such as absence of osseointegration, or resorption of peri-implant bone. In addition, unexpected problems are often experienced, such as an implant penetrating the maxillary sinus during surgery.

Moreover, complex occlusal forces are generated in the mouth during maintenance of a dental prosthesis mounted on an implant, which causes various problems including failure of the prosthesis, implant fracture, and loss of peri-implant bone.

The differences between implants and natural teeth can clearly be seen in the structure of periodontal tissues, which causes changes in blood flow to peri-implant tissues, and in the difference in susceptibility to inflammation due to discrepancies in the direction of gingival collagen fiber.

In addition, it has also been claimed that since implants are unable to absorb occlusal forces, due to the absence of the periodontal ligament that natural teeth have, excessive occlusal forces are directly transmitted to peri-implant bone, resulting in resorption of the alveolar bone. Hence, there have been a number of efforts to solve these problems. Jeong et al., reported that stability of implants was differently affected by morphological changes to the implants, surface finishing types, and forces occurring in the mouth, such as mastication[1].

Meanwhile, Park et al., performed experiments on resistance to vertical displacement imposed on implants by forming a um-

Received October 15, 2024, **Revised** November 2, 2024, **Accepted** November 15, 2024

Corresponding Author: Dong Ju Choi, Lifedental Clinic Yangpyeong, Yeokjeon-gil 24, Yangpyeong-eup, Yangpyeong 12556, Korea, Tel: +82-31-775-8081, Fax: +82-31-775-8082, E-mail: djcdavid@hanmail.net

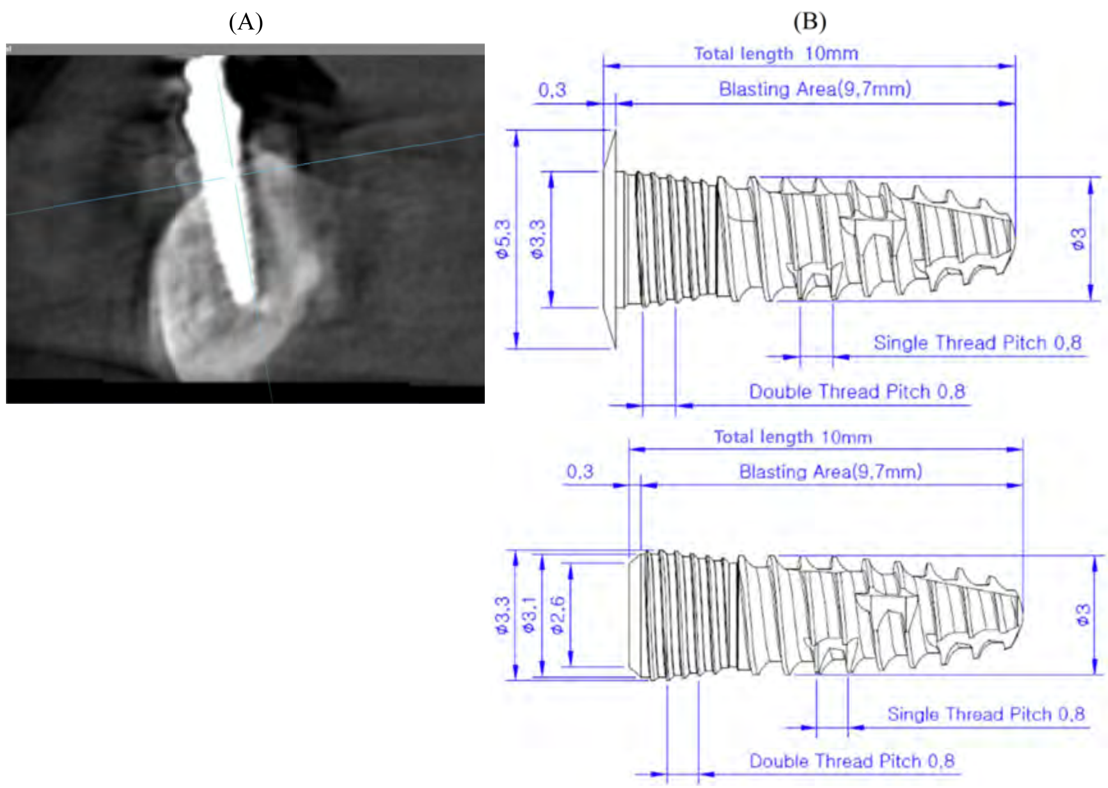


Figure 1. (A) CT Image of Implant by Left Direction (B) The Design of the new implant shape for decreasing deform; Umbrella Type (left), Conventional Type (right).

brella type structure on the top of implant. Although it was just a basic experiment without observation of the various forces, they reported that the structure had a positive effect on dispersal of forces to the implant. However, there have been no additional results.

The present authors modified the top part of the implant to an umbrella type, making a form of implant that would minimize forces transmitted to peri-implant alveolar bone and reduce displacement of the alveolar bone by forces transmitted via the implant. The resulting implants were subjected to analysis using 3D finite element analysis (FEA), in which the peri-implant alveolar bone was divided into cortical bone and cancellous bone.

On the other hand, in order to find out the response of the newly designed implant *in vivo*, the implant was implanted into the tibia of rabbits, and then fundamental experiments were conducted to find out if it was practically helpful for osteogenesis and also on improvement of osseointegration.

MATERIALS AND METHODS

1. Structure of the alveolar bone

Analysis of CT images show the implant as a structure (embedded bar, implant) inserted into the alveolar bone (cortical bone and cancellous bone). A characteristic of this structure is that once force is loaded on the implant in the mouth, the stress is transmitted to peri-implant alveolar bone. At this time, forces inducing settlement into the alveolar bone are generated, along with resistance to implant tilt, and stress is transmitted to peri-implant bone due to the forces of resistance against these forces.

In Figure 1, lateral images of the mandible were obtained through CT cross sectional images taken from an actual patient, a 3D image was constructed based on the images, and then an analysis was attempted. At this time, considering that it is rare for an implant to actually be inserted vertically in the mouth, implant was made in a tilted by 10° in the direction that occlusal force is applied to the alveolar bone. In order to maintain a consistent length, the model was constructed with a 10 mm-long implant.

In Figure 1A, by observing cross-sections taken using a cone

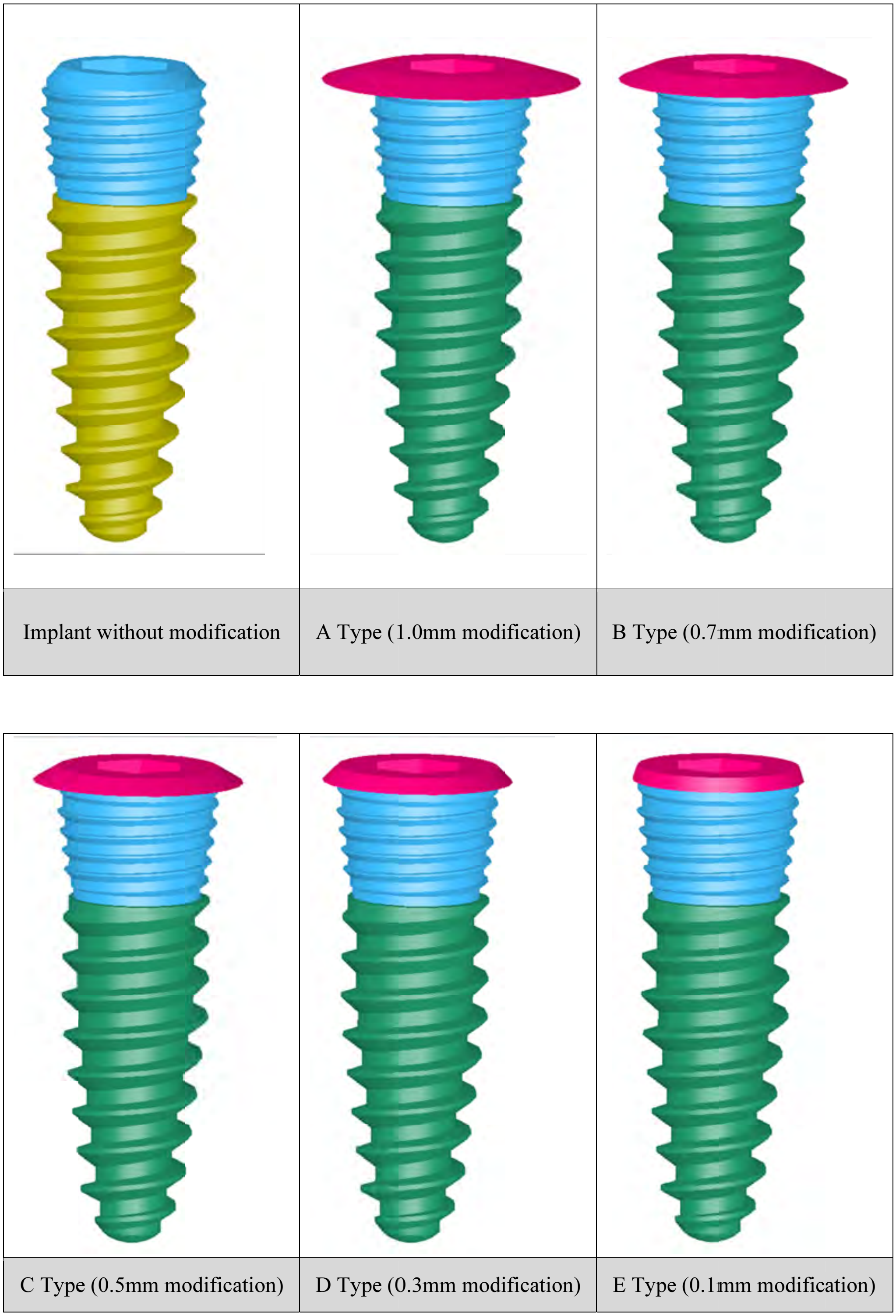


Figure 2. 3D Models of implants with 5 different modifications.

beam-CT, which is often used in dentistry, we made an FEA model from the images.

2. Implant types

The implants used in the experiments were conventional implants from Neo-biotech and umbrella type implants, in which the neck part of the conventional implants was modified. Values used for FEA were selected with reference to the implant manufacturer's design plans, and the surface of each implant used in the animal experiment was treated with RBM.

Figure 1B shows the diagrams of the conventional type and the umbrella type implant, in which the structure of the upper part was modified to have little effect on the alveolar bone and to reduce deformation (settlement and tilt) by forces.

The widths of umbrella protrusion for the umbrella type were set at 1.0 mm, 0.7 mm, 0.5 mm, 0.3 mm, and 0.1 mm, and then the ability to disperse forces resist displacement were observed for each subtype.

In Figure 2, FEA using a 3D model was performed for the conventional type and the umbrella types with varying umbrella width. Helix pitch from the middle part to the bottom part of each implant was 0.8 mm, whereas that of the upper part was 0.4 mm. In addition, protrusions were made on the top part of the umbrella type implants, which functioned to cover the alveolar bone positioned near the upper part of the implants, dispersing transmitted force, preventing infection from outside, blocking downward movement of soft tissues, and decreasing deformation of implants caused by masticatory force (Figure 2).

3. Finite Element Model

A finite element model was constructed based on CT images taken from an actual patient, in which cortical bone and cancellous bone were added, and an implant shape was inserted. The shape of the alveolar bone was made by using coordinates obtained from cone beam CT images, and extended models up to 10 mm in the z axis were made for convenience. The alveolar bone surrounding the implants was constructed as a dense mesh to increase the accuracy of analysis (Figure 3, 4).

Figure 3 shows the finite element models.

4. Comparison of material properties

Properties of materials to be applied for finite element analysis were compared with reference to the literature, and these have been summarized in Table 1.

5. Structure formation and load setting in the finite element model

Lin et al., reported that the range of occlusal force in natural teeth was 297N–669N, and the range of occlusal force after restoration by implant was 42N–412N (Lin et al., 2010), based on which the present study set 300N as the standard load. Also 300N of load was applied in the L2 direction which was defined as the oblique load. This takes into account the fact that the implants in the CT images taken to make the finite element model were tilted by 10°, and that it is generally difficult to perform perfectly vertical implantation in implant surgery (Figure 5).

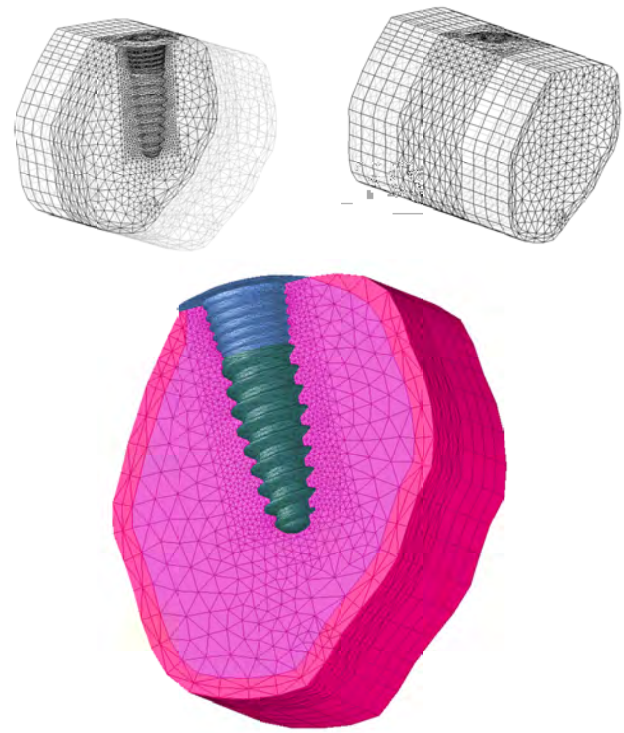


Figure 3. 3D Finite Element Model using the Visual FEA.

The loads to be applied in each direction were calculated as below, in which the direction of the implant itself was set as the vertical direction for force transfer and L2, corresponding to the direction of occlusion, was used for the oblique load in the mouth.

L2 : Oblique Load : 300 N

L1 : Vertical Load : $300 * \cos(10°) = 295.4$ N

L3 : Horizontal Load : $300 * \sin(10°) = 52.1$ N

6. Interpretation

The model was made using tetra and prism elements, the number of nodes was 13236, and the number of elements was 62902. 3D solid structure and linear static analyses were used.

7. Animal study

An animal experiment was performed to investigate the *in*

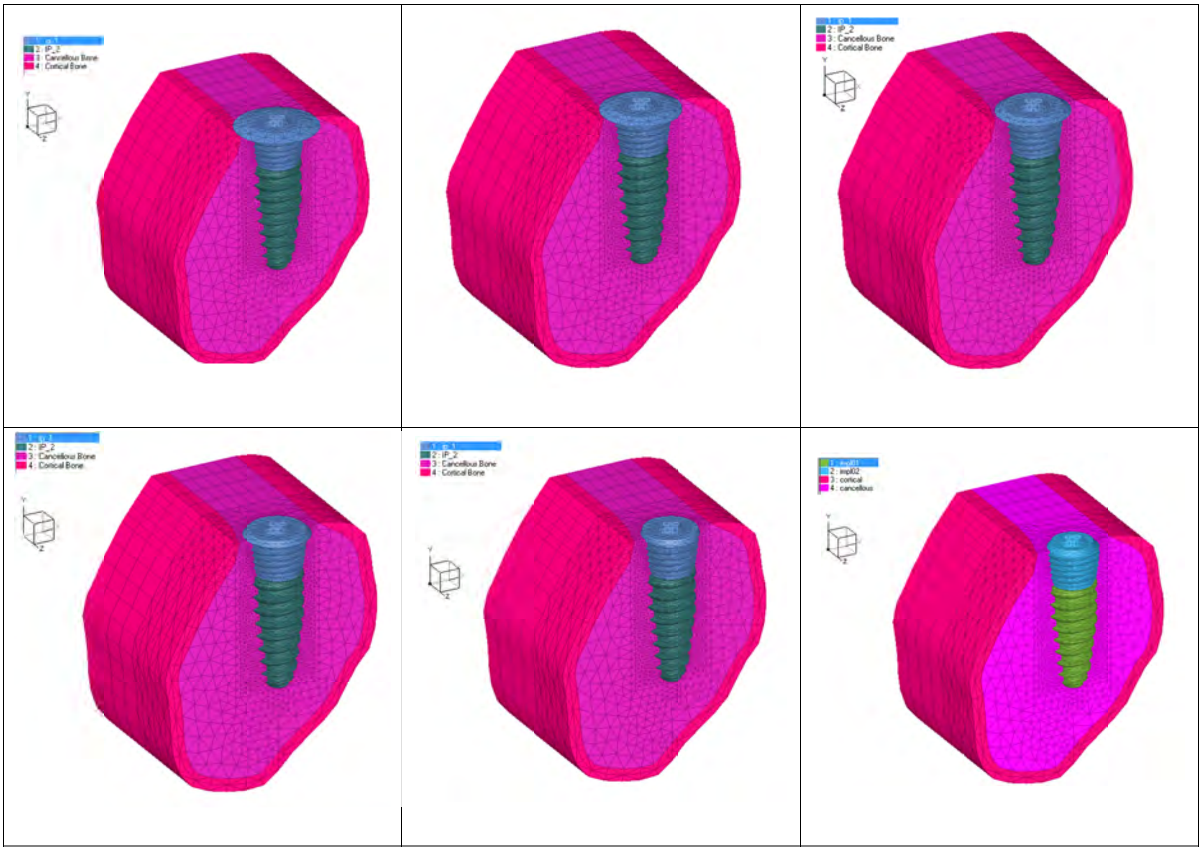


Figure 4. 3D Model demonstrating the new umbrella type implants and implant without change.

Table 1. Comparing mechanical properties of material

Material	Young's modulus	Poisson ratio
Cortical bone	14.8	0.30
Cancellus bone	1.85	0.30
Titanium	110	0.32
Cobalt-chromium alloy	220	0.30

vivo response in terms of the effect of the umbrella part of the implant on osteogenesis. 8 New Zealand white rabbits (2.5 kg) were used in the experiment. Regions to be implanted on both tibias of each rabbit were marked, followed by implantation. At this time, the widths of the region for implantation were increased by 1 mm up to 4 mm in depth from the upper part of implants on both sides, in order to measure osteogenesis (Figure 6).

Anesthesia was conducted by mixing Rompun and Zoletil in a ratio of 1:1 (0.5 cc each), and administering by intravenous injection. The implant with a 1 mm long umbrella (experimental group) and the implant without modification (control group) were inserted into the tibias of each rabbit.

Implants (Neo-biotech, Korea) with dimensions of 3.5 mm in diameter and 8 mm in length were used as fixtures in the experiment, and implants for the experimental group were made by the same manufacturer with modifications. The rabbits were sacrificed after 1 month, followed by biopsy to measure removal torque and the degree of osteogenesis. Rabbits were sacrificed by the method of mixing Rompun and Zolatil in the same ratio (0.5 cc each), followed by intravenous injection, and then air was injected into the heart (Figure 7).

Removal torque was measured by using a torque tester from Ostem, and during the biopsy, ground polished bone specimens were made together with the implants together for biopsy, followed by Villanueva stain and observation for the extent of osseointegration (Figure 8).

CONCLUSIONS

1. Umbrella type implant has better biomechanical characters by force distribution
2. Animal study shows the umbrella type implant activate more bone formation

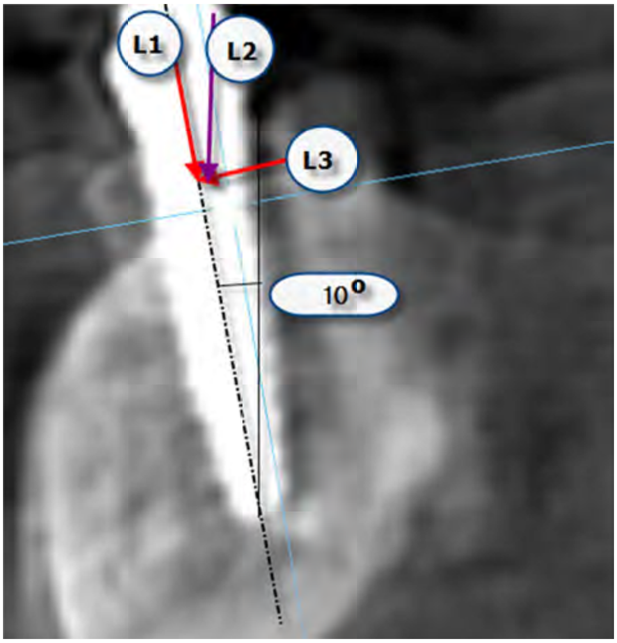


Figure 5. Applied Load and Direction.

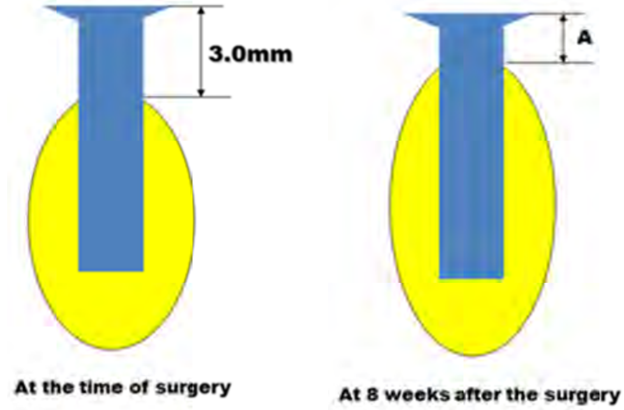


Figure 6. Both side of distance between top of implant and the alveolar crest (A) was measured. Bone gain ratio was calculated as (1−(A/3.0))×100.

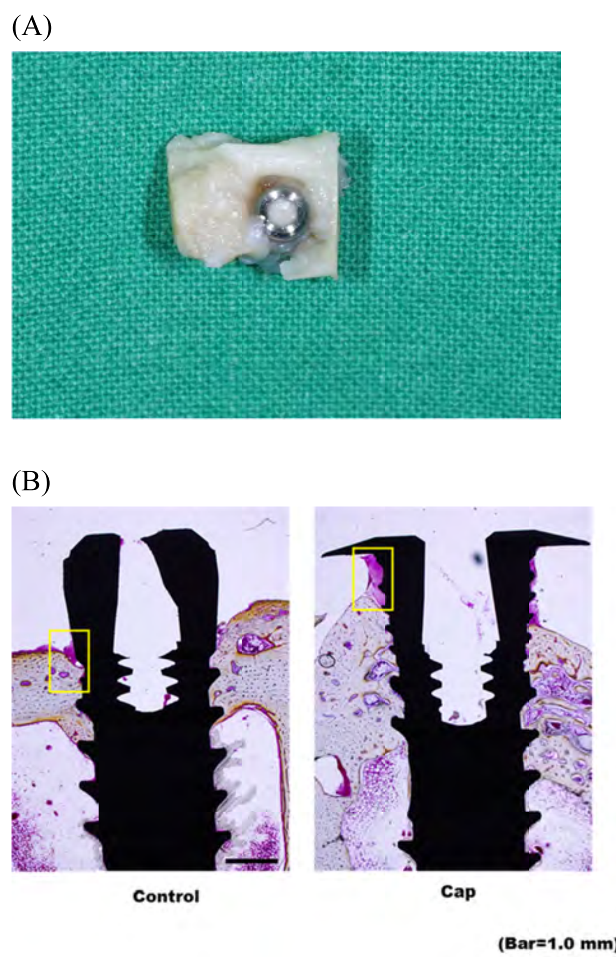


Figure 7. (A) An implant implanted in tibia of rabbit. (B) Difference of bone gaining pattern between control and experimental group.

3. Umbrella type implant can be used clinically

ANALYSIS

1. Summary

Analysis was performed on 6 implant types, including the umbrella types (Umbrella Type 1 – Umbrella Type 5) and the conventional type, for the 3 kinds of loads on implants: vertical load, horizontal load, and oblique load. In order to investigate deformation characteristics caused by occlusal forces, analysis was performed on the vertical settlement pattern of implants (settlement, Y displacement) and horizontal displacement, in terms of implant tilt (Tilt, horizontal displacement/implant length).

2. Analysis of implant deformation

Analysis was performed on tilt of implants relative to the horizontal force (Figure 9A, 9B, Table 2) and the extent of settlement degree relative to the vertical load (Figure 10A, 10B).

Figure 9A shows the implant tilt due to horizontal forces, in which the degree of tilt caused by the force on the implant was calculated by the following equation.

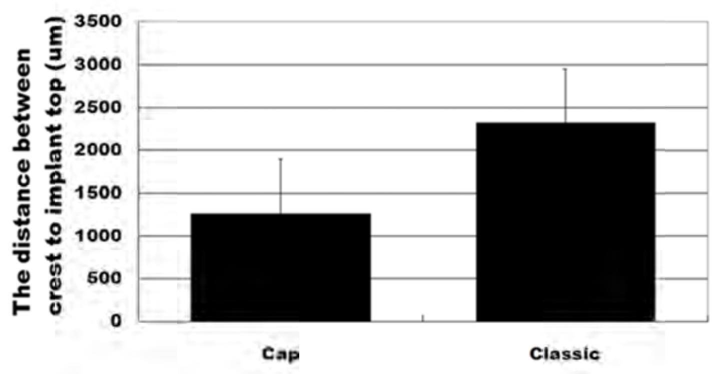
$\delta = (u_t - u_b)/H_{ip}$

δ : tilt of implant

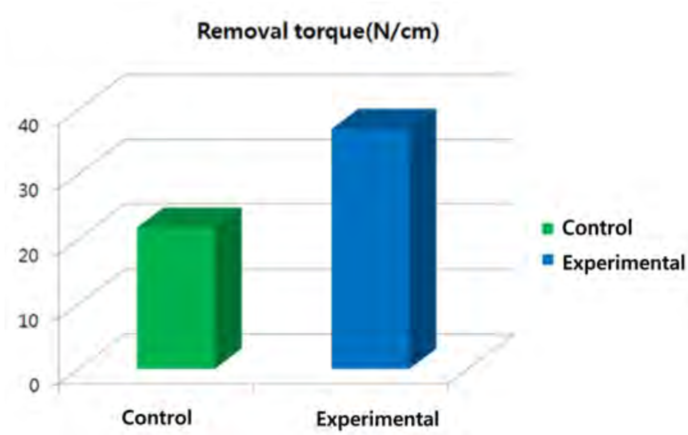
u_t : horizontal displacement of upper part of implant

u_b : horizontal displacement of bottom part of implant

(A)



(B)



21.75 ± 6.84 N/cm 37 ± 3.12 N/cm
Mann-whitney test (p=0.029)

Figure 8. (A) The distance between the alveolar crest to the implant top was 1264.2±633.0 μm in the umbrella type implant. It was 2319.8±635.8 μm in control (p=0.002). (B) Removal torque.

H_⟦ip⟧ : implant height

Figure 9B is a graph showing horizontal displacement when a horizontal force is applied to the implant, where the degree and direction of displacement are displayed according to the position from the top to the bottom of the implant. As umbrella length increased, horizontal displacement by the same load decreased and tilt became smaller, as shown in the figure.

The position for the axis of rotation in the conventional type was higher, with more severe horizontal displacement, which may cause more stress to be transmitted overall, not only to the alveolar crest, but also to peri-implant bone tissue.

Table 2 shows tilt and displacement values of the bottom part and the top part depending on implant type. The maximum displacement and the maximum tilt were found in the conventional type. In contrast, the minimum value was found in the 1.0 mm-long umbrella.

Figure 10A shows settlements by vertical load (settlement, Y displacement). Loads applied to the implant increase stress on cortical and cancellous bone, causing settlement. In the interpretation of 3D FEA, analysis of settlement makes it possibly to investigate how well an implant type adapt to human the alveolar bone.

Figure 10B shows settlement depending on position of the alveolar bone for Umbrella Type 1 – Umbrella Type 5 and the conventional type. As the implant approaches the conventional type, the extent of settlement increases, demonstrating a large inhibitory effect of the umbrella on settlement.

Table 3 shows the extent of settlement due to vertical load, in which the conventional type resulted in the highest settlement, and as umbrella length increased, settlement decreased.

(A)

(B)

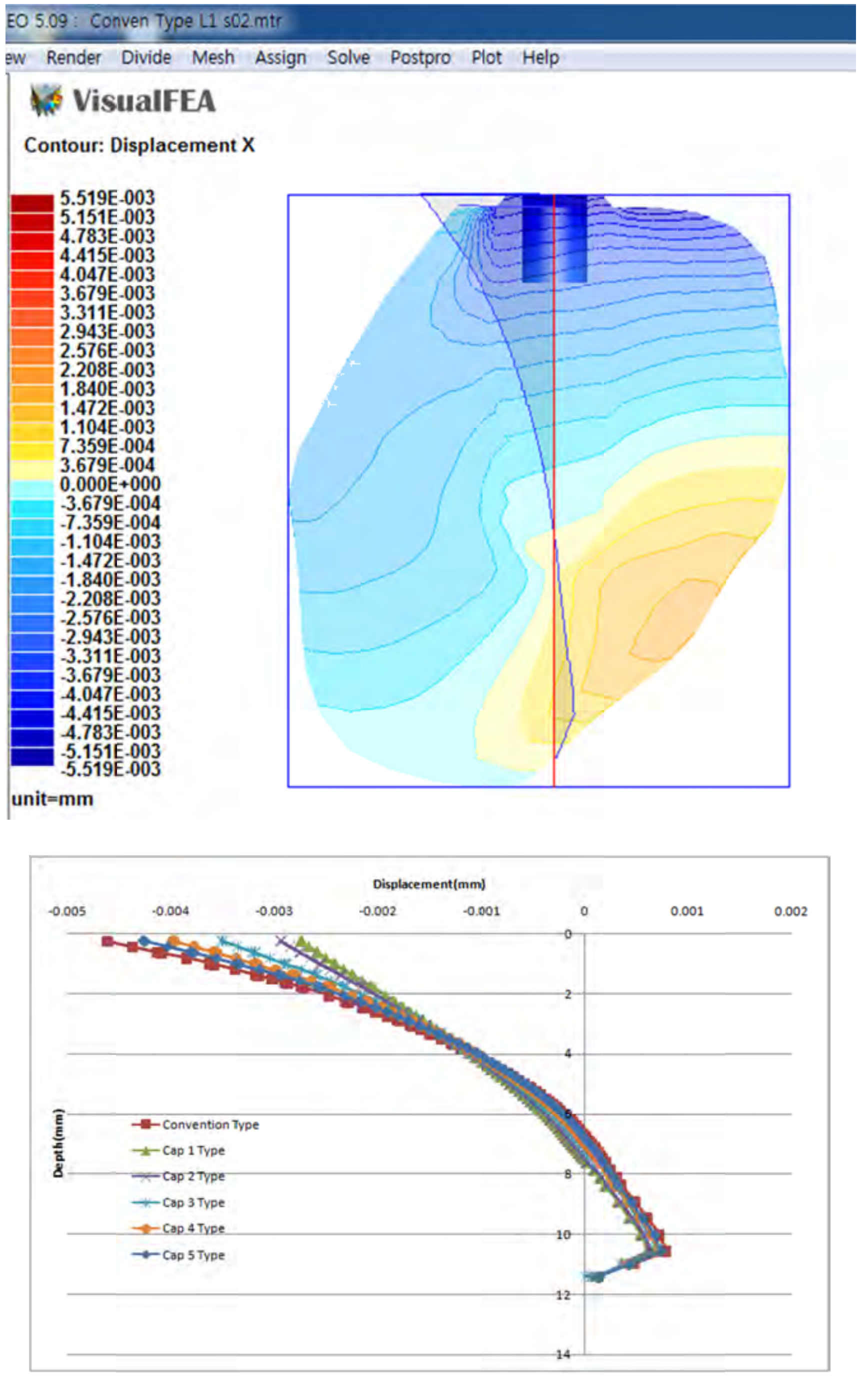


Figure 9. (A) X displacement Contour Example. (B) Comparison of Horizontal (X) displacement versus Depth.

3. Stress on the alveolar bone

Figure 11A shows von Mises stress on the alveolar bone. The bone will broken at the point where stress intensity is equal to this stress.

$$\sigma_{eq} = \sigma_{Von\ mises} = \sqrt{\frac{1}{2}\left[(\sigma_1 - \sigma_3) + (\sigma_1 - \sigma_3) + (\sigma_1 - \sigma_3)\right]}$$

$\sigma_{eq} < \sigma_a$: Safe

$\sigma_{eq} \geq \sigma_a$: Fracture or Failure

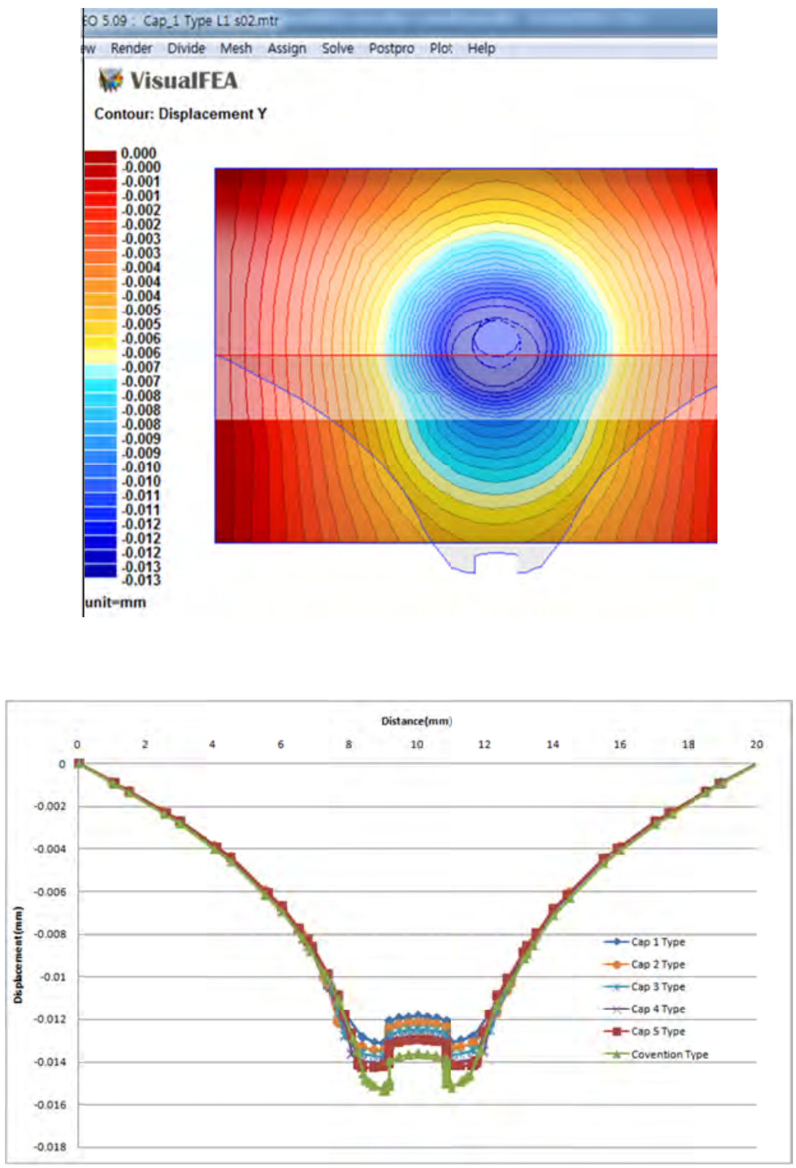
Here, σ_a : Allowable strength of applied subject

Figure 11B shows von Mises stresses calculated for cancellous

Table 2. Tilts and Displacements of the new designed implants

Items		Type of the new Shape of implants					Conventional Type
		Umbrella 1	Umbrella 2	Umbrella 3	Umbrella 4	Umbrella 5	
Tilt		3.390E-04	3.709E-04	4.407E-04	4.957E-04	5.289E-04	5.776E-04
Displacement	Bottom	5.453E-04	6.378E-04	6.971E-04	7.157E-04	7.377E-04	7.842E-04
	Top	-2.845E-03	-3.071E-03	-3.710E-03	-4.241E-03	-4.551E-03	-4.992E-03

(A)



(B)

Figure 10. (A) Settlement (Y displacement) by Vertical Load. (B) Comparison of Settlements (Y displacement) versus Distance.

bone and cortical bone, where stress on cortical bone was found to be higher for Umbrella Types 1 and 2. In contrast, there was no outstanding difference in the stress on cortical bone calculated for Umbrella Type 3 – Umbrella Type 5, and the conventional type.

In addition, stress on cancellous bone was smaller for Umbrella Type 1 – Umbrella Type 3, whereas stress was found to be higher for Umbrella Types 4 and 5 and the conventional type. The umbrella size was bigger in the umbrella type implants in

Table 3. Settlements of the new designed implants and Conventional Type

Items	Type of the new designed implants					Conventional Type
	Umbrella 1	Umbrella 2	Umbrella 3	Umbrella 4	Umbrella 5	
Settlement (mm)	1.314E-02	1.348E-02	1.376E-02	1.406E-02	1.427E-02	1.534E-02

(A)

(B)

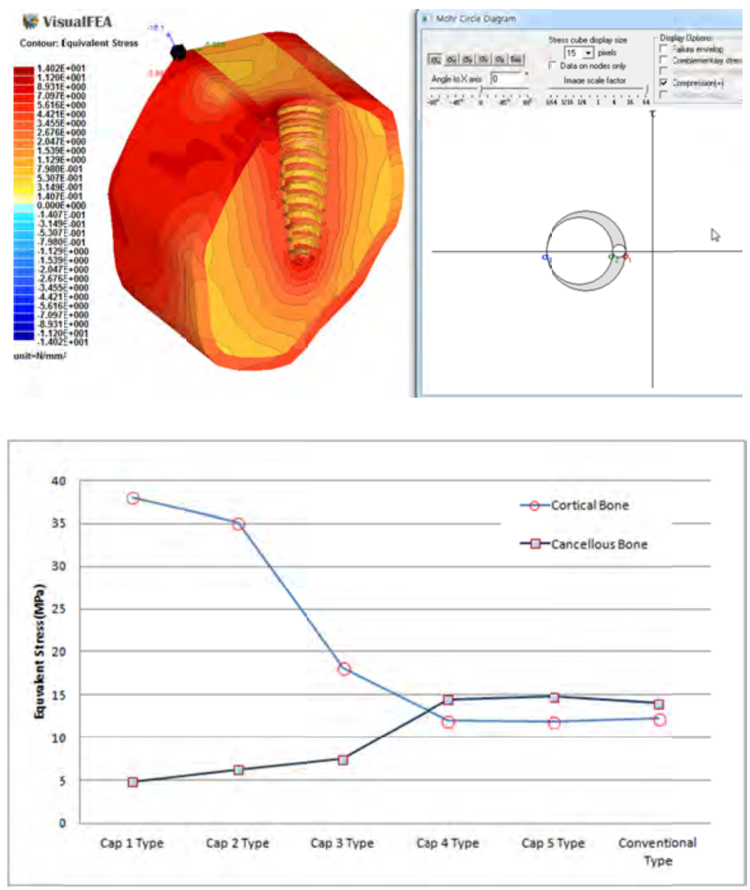


Figure 11. (A) Concept of von Mises stress. (B) von Mises Stress (conventional type implants versus the new designed implants).

which the umbrellas directly contacted the cortical bone, which tended to reduced stress on cancellous bone, while increasing stress on cortical bone.

Table 4 shows equivalent stress, or von Mises stress. The stresses generated on cortical and cancellous bone changed dramatically from umbrella type 4. Based on this table, it is determined that the umbrella type implants effectively decreased stress on the alveolar bone (Table 4).

DISCUSSION

Design of implants is a highly important factor for determining not only the surgical method for implantation, but also the properties of the implant. In particular, successful fixation of the implant in the bone and the maintenance of a stable state are crucial elements in the osseointegration process. In addition, implant design also affects maintenance of the alveolar bone and the occurrence of periodontal disease following long-term use of the implant.

Kim et al., studied initial responses of proximal tissues depending on implant type by inserting 3 trans mucosal type implants into Beagle dogs. They reported that implant type affected the difference in bone resorption and the level of proximal soft tissue formation. In addition, they claimed that more initial con-

Table 4. Equivalent (von Mises) Stress of Cortical Bone and Cancellous Bone (MPa).

Items	New Shape of implants					Conventional Type
	Umbrella Type 1	Umbrella Type 2	Umbrella Type 3	Umbrella Type 4	Umbrella Type 5	
Cortical Bone	38.05	35.2	18.2	12	11.9	12.2
Cancellous Bone	4.841	6.246	7.49	14.5	14.8	14

nective tissue would be more helpful in the long term prognosis of the implant, because the tissue would be maintained even after the implant had fulfilled its function. This is interpreted to be consistent with existing knowledge of the relationship between biologic width and the health of the periodontal tissue[3].

Elias et al. studied the effects of different implant morphologies, surface appearance, surgical methods, and bone quality on initial fixation of implants. According to their study, influencing factors on initial fixation were the condition of the alveolar bone, surgical method, and design of implant[4], and a number of researchers have made efforts to increase initial fixation and success rate of implantation by modifying the design, length, and width of implants[5-7].

On the contrary, Norton reported that secondary implant stability, which is a process caused by remodelling of osseous tissue after implantation of implant in the bone, is more important than simple initial fixation. Hence, Norton even claimed that it would be unnecessary to apply a force of at least 20 Ncm in implantation of a standard sized implant[8]. This claim is based on a study by Barewal et al., in which any implant would lose its stability after 3~4 weeks no matter how firmly the implant was established in the bone. In particular, Barewal et al. reported a difference in the change in initial fixation depending on the presence or absence of cortical bone, whereas it seems that the umbrella design in the present study was helpful in fixation external to the bone tissue, meaning that this design could increase initial fixation ability when cortical bone was weak[9].

Pilliar RM reported that implant design affected remodelling of peri-implant bone. In addition, when bone tissue was absorbed at the upper part of implant, and osseointegration occurred only at the bottom part of implant, it is thought that bending forces could increase the chance of mechanical fatigue fracture by masticatory force. This phenomenon has been also reported to occur in prostheses applied to the hip joint or knee joint, where it was also mentioned that prostheses with a rough surface had a high osseointegration effect[10,11].

Park et al. attempted to increase initial fixation ability during implantation and minimize the stress on the alveolar bone by modifying the neck design of the implant[12]. A umbrella structure was added to the neck of the implant, and then degree of displacement of implant in response to vertical and horizontal forces loaded on implant, as well as the level of stress to peri-implant bone, were observed using a finite element method. In the results of this experiment, the implant with a umbrella structure had a much higher resistance to displacement by vertical and horizontal forces than conventional implants, and stress transmitted to peri-implant bone also remarkably decreased. In addition, stress was mostly transmitted to the surface of cortical bone, meaning that the implant is placed in a highly stable condition within the alveolar bone. Therefore initial fixation ability of the implant should increase, and the ability to tolerate excessive occlusal force should be enhanced.

It is a well known fact that optimal dispersal of occlusal force in the mouth significantly affects the long term prognosis of implants, so there have been attempts for a long time to analyze the force applied to implants by occlusal force, as well as the influence of this force on the surrounding region. Various methods were attempted before the finite element method became universal. In particular, French et al. used a photoelastic model to analyze transmission of stresses to peri-implant region by type, and also performed a comparative analysis of implants designed to properly disperse occlusal force[13-15].

In addition, Torsiglieri et al. performed an experiment in which they made a model of a severely atrophied mandible, conducted implantation with various types of implants, applied a force directly, and measured the ability of the implants to withstand forces in poor bone quality and their ability to tolerate forces in the mouth. They also performed observations in which they standardized the morphology of the mandible, and measured and observed the output after applying forces directly[16].

In the present study, we were able to apply forces with an actual direction and intensity in the mouth by using an FEA that was structurally similar to the actual situation in the mouth. Direction of force and elasto-plastic behavior of the areas affected by it were determined with reference to a study by Lee et al[17].

Simsek et al. applied a vertical force, a force tilted buccolingually by 60°, and a horizontal force, based on vertical implantation into the jaw, and measured the compressive and tensile forces that were transmitted to the jaw using a finite element model. When forces were transmitted to the neck part of the implant, a tensile force was conveyed to the buccal side, and a compressive force was conveyed to the lingual side. As the gap between two implants was wider, tensile force to the buccal side increased, whereas when the gap between two implants was narrower, compressive force to the lingual side increased[18].

Multiple researchers have conducted studies using finite element methods to assess the effects of implant design on peri-implant bone, and effects have been reported according to the cross section of implants, as well as differences in transmission of force depending on the upper structure of implants[19,20]. In particular, Bozkaya et al. analyzed the concentration of forces according to the implant region, by direct applications of various forces using 5 types of commonly used implants available commercially. They found that stresses from conventional occlusal force were concentrated on the upper part where the cortical bone was, regardless of implant type. In general, this phenomenon may be because the force loaded on the implant had effects on physiological phenomena at the border area between the upper part of the alveolar bone and implant, regardless of implant type.

The present study applied 300 Ncm of vertical force, calculated the oblique force and horizontal force loaded on implant with 10° of tilt using a 3-D model, and applied the force working in each direction. Erkman et al. also used 300 Ncm of vertical force and a 3-D FEA model, in which they compared biomechanical responses to forces loaded on two different materials using a 3-D model[21].

When the results of the present study are analyzed, as the force is concentrated on the upper part of the implant where it contacts cortical bone, there was a decrease in stress inside the alveolar bone, where the majority of contact between the implant and bone occurs. Since this implant shape is a highly advantageous structure for stable maintenance within the bone, it is considered greatly helpful in promotion of initial osteogenesis for patients with poor bone quality.

In addition, an increase of resistance in the umbrella area greatly suppresses the extent of downward settlement of the implant due to vertical forces, so that the umbrella type is highly advantageous for preventing the implant from entering the maxillary sinus in cases of maxillary sinus augmentation, where the implant often fails to hold the load due to poor bone quality.

Therefore, it is expected that the required time from implantation to loading of masticatory force would be reduced, and this early restoration of masticatory force would elevate satisfaction of patients. Multiple researchers have been studying ways of reducing the time from implantation to loading, and Szmukler-Moncler et al., proposed more detailed and reasonable standards. In particular, they suggested that, in the early stages, patients should carefully and strictly decide the time a force or load needs to be suddenly applied, and that success rate should be increased through modifications, such as the method of using a splint to connect implants together and minimize micromotion[22].

In addition, since the umbrella type implant promoted osteogenesis at the bottom part in animal experiment, clinical application of the umbrella type implant would be helpful for osteogenesis at the peri-implant region, leading to elevation of torque generated during removal of implant, and promotion of osteogenesis at the peri-implant region. Therefore, this implant design is considered to give additional stability to the implant when implantation is performed on area with severe bone loss or poor bone quality, and it is also expected to have positive outcomes when applied in practice.

CONCLUSION

3D FEA was performed on newly designed umbrella type implants, and the effects of the implant modifications on the alveolar bone (cortical bone and cancellous bone) were as follows:

- As umbrella length increased, settlement and tilt of implant decreased, indicating that the umbrella was highly effective for stable establishment of the implant in the bone.

- Stress on cortical bone was calculated to be higher for wider umbrellas, whereas the 0.3 mm umbrella had a smaller effect on stress reduction. In contrast, stress on cancellous bone increased as the umbrella width decreased, and the 0.3 mm umbrella showed the minimum stress reduction.

- As the umbrella width increased, the implants showed an improvement in stable establishment, and stress on cortical bone increased, while stress on cancellous bone decreased.

Therefore, the umbrellas 0.3 mm~0.5 mm in length are considered optimal, based on their stabilizing effect for establishment, and relatively small impact on osseous tissue. In addition, it is also necessary to consider methods to prevent concentration of stress at the site where the umbrella directly contacts to the osseous tissue by making the margin of the umbrella into a round shape.

REFERENCES

1. Chung JM, Jo KH, Lee CH, Yu WJ, Lee KB. Finite element analysis of peri-implant bone stress influenced by cervical module configuration of endosseous implant, Journalof Korean academy of prosthodontics 2009;47:394-404.
2. Lin D, Li Q, Li W, Duckmanton N, Swain M. Mandibular bone remodelling induced by dental implant. J Biomech 2010;19:287-293.
3. Kim S, Oh KC, Han DH, Heo SJ, Ryu IC, Kwon JH, Han CH. Influence of transmucosal designs of three one-piece implant systems on early tissue responses: A histometric study in Beagle dogs. Int j oral maxillofac implants 2010;25:309-314.
4. Elias CN, Rocha FA, Nascimento AL, Coelho PG. Influence of implant shapr, surface morphology, surgical technique, and bone quality on the primary stability of dental implants. J mechanical behavior of biomedical materials 2012;15:169-180.
5. Chiapasco M, Gatti C, Rossi E, Haefliger W, Mark walder TH. Implant-retained mandibular overdentures with immediate poading. Clini Oral Impl Res 1997;8:48-57.
6. Freitas Jr. AC, Bonfante EA, Giro G, Janal MN, Coelho PG. The effect of implant design on insertion torque and immediate micromotion. Clin Oral Impl Res 2012;23:113-118.
7. Conrado Aparicio, et al. In vivo evaluation of micro-rough and bioactive titanium dental implants using histometry and pull-out tests. The Mechanical behavior of biomedical materials 2011;4:1672-1682.
8. Norton M. Primary stability verus viable constrain - a need to redefine. Int j oral maxillofac implants 2013;28:19-21.
9. Barewal RM, Oates TW, Meredith N, Cochran DL. Resonance frequency measurement of implant stability in vitro on implants with a sendblasted and acid-etched surface. Int j oral maxillofac implants 2003;18:641-651.
10. Pilliar RM, Deporter DA, Watson PA, Valiquette. Dental implant design-effect on bone remodeling. J Biomed Mater res appl biometer 1991;25:467-483.
11. Pilliar RM. Porous-surfaced metallic implants for orthopedic applications. J Biomed Mater res appl biometer 1987;21:1-33.
12. Park JW, Kim SG, Choi DW, Choi MR, Yoon YJ, Park JW, Choi DJ. Study of a wing-type implant on stress distribution and bone resorption at alveolar crest. J Korean AssocOral Maxillofac Surg 2012;38:337-342.
13. Franch AA, Bowles CQ, Partam JD, Eick JD, Kiloy WJ, Cobb CM. Comparison of peri-implant stress transmitted by four commercial available osseointegrated implants. Int J periodont Restorativ dentist 1989;9:221-230.
14. Roberts WE, Garetto PG, DeCastro RA. Remodeling of devitalized bone threatens periosteal margin integrity of edentulous titanium implants with threaded or smooth surfaces: indication for provisional loading and axially directed occlusion. Journal of Indiana dental association 1989;68:19-24.
15. Albreksson A, Jansson T. Osseointegrated dental implants, Dental Clinics of North America 1986;30:151-174.
16. Torsiglieri T, Raith S, RA, Deppe H, HölzleF, Steiner T. Stability of edentulous, atrophic mandibles after insertion of different dental implants. A biomechanical study, Journal of cranio-maxillo-facial surgery 2015;43:616-623.
17. Lee JY, Ahn SY. Interactive visualization of elasto-plastic behavior through stress pasths and yield surfaces in finite element analysis. Finite Elements in Analysis and Design 2011;47, Elsevier.
18. Simsek B, Erkmen E, Yilmaz D, Eser A. Effects of different inter-implant distances on the stress distribution around endosseous implants in posterior mandible: A 3D finite element analysis. Medical Engineering & Physics 2006;28:199-213.
19. Abu-Hammad O, Khraisat A, Rar-Odeh N, El-Maaytah M. Effect of dental implant cross-sectional design on bone structure using finite element analysis, Clinical implant dentistry and related research 2007;9:2007.
20. Bozkaya D, Muftu S, Muftu A. Evaluation of load transfer characteristics of five different implants in compact bone different load levelsby finite elements analysis. J Prosthet dent 2004;92:523-530.
21. Erkmen E, Meric G, Kurt A, Tunc Y, Eser A. Biomechanical comparison of implant retained fixed partial denture with fiber reinforced composite verus conventional metal frameworks: A3D FEA study. J mechanical behavior of biomedical materials 2011;4:107-116.
22. Szmukler-Moncler S, Piattelli A, Favero GA, Dubruille JH. Considerations preliminary to the application of early and immediate loading protocolsin dentalimplantology. Clin Oral Implan Res 2000;11:12-25.