A three-dimensional finite element analysis of osseointegrated implant on stress distribution in different abutment designs and fixture diameters

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I. Introduction

Prostheses supported by osseointegrated implants have been used for restorations in oral functions since Dr. Brånemark introduced them into the clinical field[7]. At first, clinicians used dental implants for fully edentulous patients[7], and soon they started to use them for the partially edentulous patients and single tooth missed patients. Now many dentists seem to expand the clinical field of dental implant into general practice.

The implant systems were developed from early primitive implants to modern ones with various features. The early implant systems were made for the restoration of the masticatory functions for the fully edentulous patients [7], When osseointegration was first introduced to Korea and other countries, function and not esthetics was of primary concern[7,22]. As esthetics became primary concern by the demand of the patients and through time[31], esthetic abutments which had subgingival margins appeared. EsthetiCone system, CeraOne system, UCLA system, and MirusCone system were some of the examples[35].

Standard fixtures, 3.75mm in diameter were used mainly for incisor and premolar region for the fully edentulous patients. Thereafter, the clinicans applied the dental implants to the partially edentulous sites, and they began to place it to the posterior region due to developments of surgical skills. But, they were confronted with various limitations. Their demands created the diverse diameter fixtures. A wide fixture of 5mm diameter was developed for the site where standard fixture was intended to be used but wide fixture is more favorable, and this fixture was different from the standard fixture in morphological characteristics[28].

The interface between the bone and the fixture transfers occlusal forces directed the prostheses and abutments around the surrounding bone. These loadings bring about the biological reactions at the interface[5]. The sha-

* Supported by a grant No. 02-94-261 from the Seoul National University Hospital Research Fund.

pes of the implant should be designed, not to cause unfavorable reaction such as bone resorption. The implant should be able to bear the occlusal loadings ; therefore, the biomechanical analysis of the structure was a necessity.

Various methods[16,23] were used to analyze the stress in complex structures when they were loaded, for example photoelastic analysis. And among these methods, the finite element analysis was very useful in cases of analyzing stress which was generated from of external force in complex stuctures. This method proved to be a useful tool in estimating stresses around implants in different designs[12,29,45]. The finite element analysis offered some advantages, including accurate representation of complex geometries, easy model modification, and representation of the internal state of stress of all structural components and other mechanical quantities[19,33,43]. Displacements and stresses resulted from the FEM study were an approximate values, but comparisons of the amount of displacement and stress distribution in different implant systems were possible[33].

In finite element analysis, 1-dimensional, 2-dimensional and 3-dimensional methods were possible[47]. Two of these methods, 2-dimensional and 3-dimensional methods were appropriate in analyzing dental implant. All two-dimensional studies claimed that translation of the clinical condition to a two-dimensional model gave sufficient insight to the behavior of bone around dental implants[39]. But Ismail et al. compared the results of two- and three- dimensional models after loading them from different directions. The results of the two models differed in both the amount of stress generated and in the ratio between the amount of stresses for the different directions of loading[20].

The purpose of this study was to compare stress distributions among the models where EsthetiCone abutment, MirusCone abutment and a standard abutment were connected to a fixture of 3.75mm in diameter and 10mm in length, and the model of standard abutment which was also connected to a wide fixture which was 5mm in diameter with same length using three-dimensional finite element analysis study.

II. Material and methods

1) Geometry

The FEMB(ETA corporation) was the software for the construction of the models. All the software used in this study were mounted on DEC 3000/8000 workstation(DIGITAL). To investigate the internal stress of implant system and the bone, each component was designed individually. Models were created to represent the following component.

① Model 1 : 3.75mm in diameter and 10 mm in length threaded fixture, 3.0mm standard abutment, abutment screw, 3.0mm gold cylinder, gold screw, gold crown

② Model 2 : 3.75mm in diameter and 10 mm in length threaded fixture, EsthetiCone abutment with 1mm collar, abutment screw, gold cylinder, gold screw, gold crown

③ Model 3 : 3.75mm in diameter and 10 mm in length threaded fixture, MirusCone abutment with 1mm collar, abutment screw, gold cylinder, gold screw, gold crown

④ Model 4 : 5.0mm in diameter and 10mm in length threaded fixture, 3.0mm standard abutment, abutment screw, 3.0mm gold cylinder, gold screw, gold crown

These models were based on Brånemark components. The geometries of these implants were obtained from the measurements of implant component with vernier calipers and digitation of photographs presented by the manufacturer. Every effort was given to simulate real implant component as much as possible. But, in components which had threaded portions, part of threads reflected the original one and in the other part, a symmetry of long axis was assumed. Although this type of symmetry does not exit in threads, the stresses would not be significantly affected by this assumption[36]. Contact surfaces between individual components were defined as being initially unloaded and in contact. A piece of bone of 20mm in length, 20mm in width and the same size in height was built. The cortical bone at the neck of the implant was assumed to be 2mm in thickness and the same thickness at the bottom of the bone block[2,3,8,38]. A fixed bond between the bone and implant along with whole interface was assumed[6,23,33]. The implant was assumed to be placed at the center of cubic bone. And to compare the stresses under different forces, the distances from the shoulder of the fixture to the top of the gold crown in all the models were made the same. Finally, the mesh generation resulted in 6,126 nodes and 5,966 elements in model 1, 5,929 nodes and 5,656 elements in model 2, 6,222 nodes and 5,836 elements in model 3, and 6,126 nodes and 5,966 elements in model 4.

2) Material properties

Because of the absence of the precise material properties of bone, assumptions were made : the cortical and cancellous bone were isotropic, homogeneous and linearly elastic. The same assumption was also applied to the other components in the model. Fixture, abutment cylinder and abutment screw were assumed to be made out of titanium with a Young's modulus of 10,500kg/mm² and a Poisson's ratio of 0.30, gold cylinder and gold screw made out of ADA type IV gold with a Young's modulus of 98,000kg/mm² and a Poisson's ratio of 0.45. Young's modulus of the cortical bone was assumed to be ten times higher than that of the cancellous bone, and the gold crown was assumed to be made out of type III gold with a Young's modulus of 66.000kg/mm² and a Poisson's ratio of 0.33. Table I shows the material properties used[4,11,13,26,30,43].

3) Restraints

To prevent the movement of the structure, the inferior border of bone block was fixed[24,34].

4) Load

The loading forces on the models were static ones[29,33]. For the model used in this study, three forces from different directions were selected : [33,29]a horizontal bite force(0°), a vertical bite force(90°), and a oblique bite force (120°). The amount of force was 20kg in all cases(Fig. 1).

5) Solution

Solving program used in this study was MSC/NASTRAN(MSC). The von Mises stress calculated in each model was compared to one another at each component. Stress distributions presented as color difference were

Table I. Material Properties

	Young's modulus(Kg/mm²)	Poisson's ratio
titanium	1.05E+04	0.30
cortical bone	1.40E+03	0.32
cancellous bone	1.40E+02	0.30
type III gold	6.60E+04	0.33
type IV gold	9.80E+04	0.45

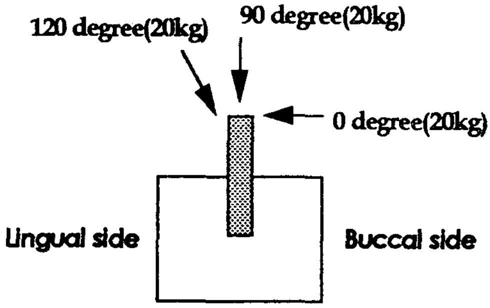


Fig 1. Buccolingual bone section with implant and bite force directions and magnitudes.

investigated to find out the place where the stress concentration occurred. The postprocessing program used in this study was I-DEAS (SDRC).

III. Results

In all models, stress distributions were similar. Maximum stress occurred at the gold screw, gold cylinder, and abutment cylinder in general. And in comparing the stresses under different forces maximum stress occurred when transverse force was applied, and minimum stress value occurred under vertical force. The von Mises stress observed in bone and implant are found in Fig 2, 3, 4.

1. Model 1

Table II, Fig. 5 and Photo. 1−12 show the von Mises stress in the model 1. In model 1, where standard abutment had been connected to 3.75mm diameter fixture, the stress

Fig. 2. The Von Mises Stresses under Vertical Force.

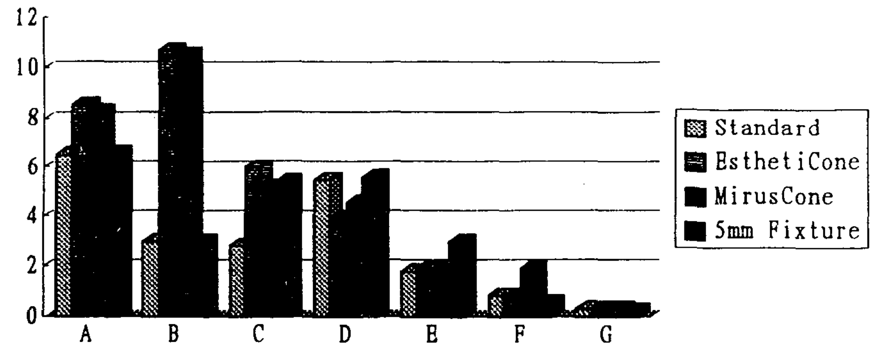
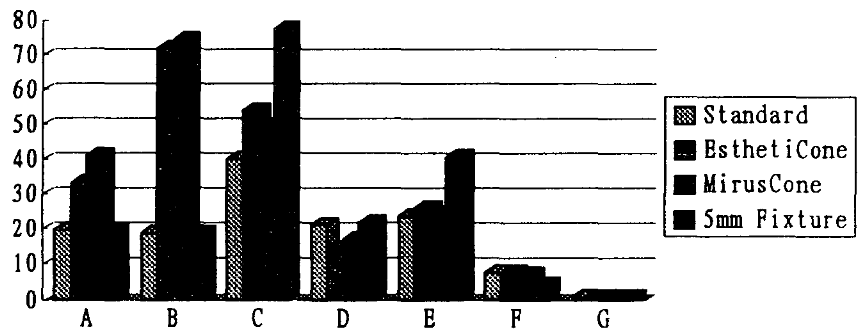


Fig. 3. The Von Mises Stresses under Oblique Force.



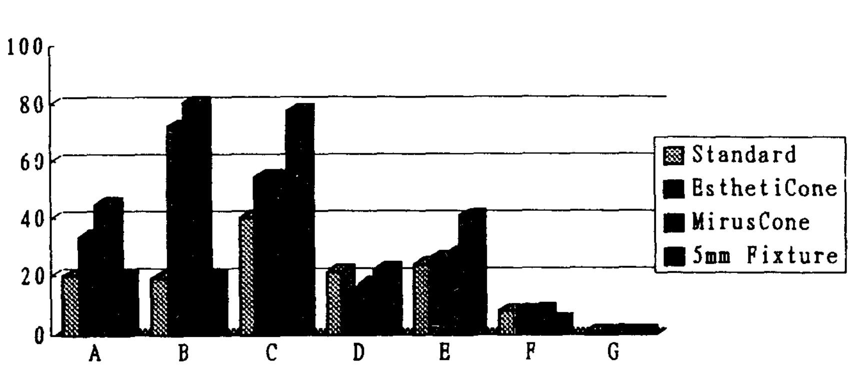
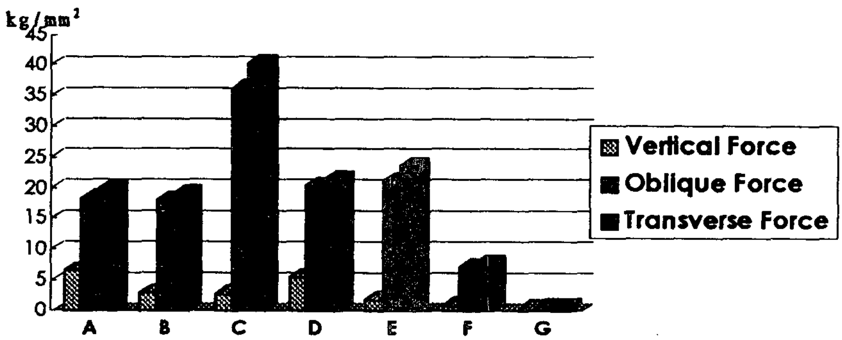


Table II. The Von Mises Stresses in the Model 1(Kg/mm²)

position / force	A	B	C	D	E	F	G
vertical	6.543E+00	3.013E+00	2.813E+00	5.506E+00	1.831E+00	8.506E−01	2.776E−01
oblique	1.825E+01	1.796E+01	3.609E+01	2.031E+01	2.107E+01	7.081E+00	4.883E−01
transverse	1.985E+01	1.905E+01	4.021E+01	2.130E+01	2.359E+01	7.701E+00	5.030E−01

A : Gold screw
B : Gold cylinder
C : Abutment cylinder
D : Abutment screw
E : Fixture
F : Cortical bone
G : Cancellous bone



distributions were relatively even. Maximum stress concentration occurred at the neck of a gold screw under a vertical force, and at the upper portion of the abutment cylinder that is in contact with a gold cylinder under the other forces. The stress concentration on a gold crown was excluded, because this stress was influenced mainly by direct loading.

In the superstructure, maximum stress concentration occurred at the neck of a gold screw, and high stress values were found all over the gold screw and at the neck of the abutment screw. In the bone, stresses were distributed along the upper cortical bone layer and the maximum value was found at the cortical bone adjacent to the neck of the fixture. These observations were in concord with the results of previous studies[4,15,25,26,33]. Except the upper cortical bone, high stress values were found at the cancellous bone around a fixture apex. But the value of the von Mises stress of the cortical and the cancellous bone was lower than that of internal structure of the implant. In the fixture, maximum stress occured at the upper portion of a fixture which was in contact with a abutment cylinder, and at the upper two third of a fixture which was connected to abutment screw. The value of the von Mises stress value in the each component of implant under the vertical force was far lower under the oblique and transverse force. And, maximum stress occurred at the upper portion of abutment cylinder contacting with gold cylinder rather than at the neck of the gold screw.

2. Model 2

Table III, Fig. 6 and Photo. 13−24 show the von Mises stress in model 2. In model 2 where EsthetiCone abutment was connected to 3.75mm diameter fixture, stress distributions were approximately similar to that of model 1, but the stress values were generally higher.

In the superstructure, the maximum stress concentration occurred at the gold cylinder and next to the neck of the gold screw. In the bone, the upper cortical bone adjacent to the fixture showed maximum stress concentration, and the stresses had spread out over the corical bone. In the cancellous bone around the fixture apex stress concentrations appeared.

Oblique force and transverse force brought about higher stress concentration than verical force on the whole, and the two forces acted similarly to vertical force in the stress distribution. But, the maximum stress was noticed on the gold cylinder.

3. Model 3

Table IV, Fig. 7 and Photo. 25−36 show the von Mises stress in model 3. In model 3 where MirusCone abutment connected to

Table III. The Von Mises Stresses in the Model 2(Kg/mm²)

position / force	A	B	C	D	E	F	G
vertical	8.503E+00	1.071E+01	6.022E+00	3.886E+00	1.853E+00	8.393E−01	2.787E−01
oblique	3.158E+01	6.345E+01	4.989E+01	1.380E+01	2.309E+01	7.100E+00	4.892E−01
transverse	3.342E+01	7.189E+01	5.418E+01	1.371−+01	2.574E+01	7.729E+00	5.038E−01

A : Gold screw
B : Gold cylinder
C : Abutment cylinder
D : Abutment screw
E : Fixture
F : Cortical bone
G : Cancellous bone

Fig. 6. The von Mises Stresses in Model 2.

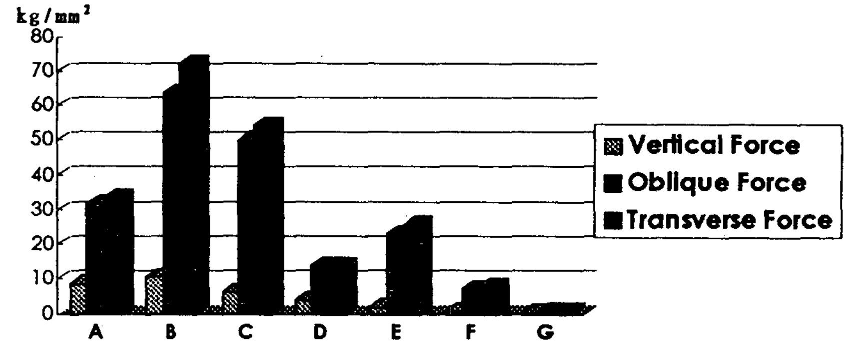
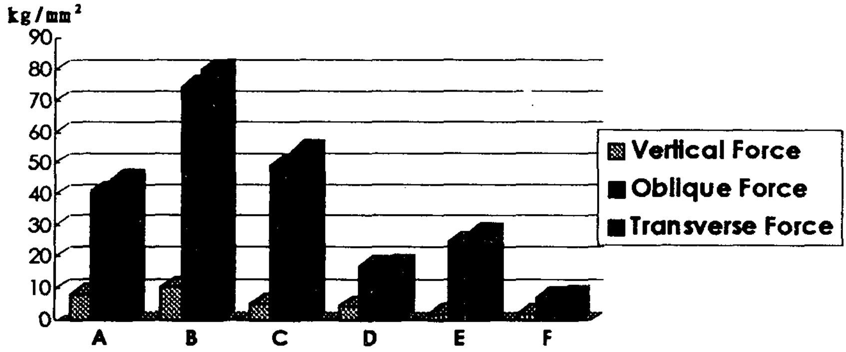


Table Ⅳ. The Von Mises Stresses in the Model 3(Kg/mm²)

position / force	A	B	C	D	E	F	G
vertical	8.254E+00	1.052E+01	5.270E+00	4.621E+00	1.884E+00	8.484E−01	2.788E−01
oblique	4.110E+01	7.462E+01	4.929E+01	1.721E+01	2.465E+01	7.172E+00	4.891E−01
transverse	4.472E+01	8.012E+01	5.394E+01	1.726E+01	2.745E+01	7.806E+00	5.036E−01

A : Gold screw
B : Gold cylinder
C : Abutment cylinder
D : Abutment screw
E : Fixture
F : Cortical bone
G : Cancellous bone

Fig. 7. The von Mises Stresses in Model 3.



3.75mm diamenter fixture presented similar stress distribution to model 2.

In the superstructure, maximum stress occurred at the gold cylinder, and next to the neck of the gold screw, like in model 2. In the bone, stress concentrations in the upper cortical bone and in the cancellous bone around fixture apex were alike in model 1 and model 2. In the fixture, stress distribution was similar to the results of model 1 and model 2. The maximum stress value was lower in some component under vertical force than in model 1 and model 2. But under the oblique and transverse force, the stress value was higher than the values of model 1 and model 2 in nearly all the components.

4. Model 4.

Table V, Fig. 8 and Photo. 37－48 show the von Mises stress in the model 4. In model 4 where standard abutment connected to 5mm wide diameter fixture, overall stress distribution was roughly alike in the previous models.

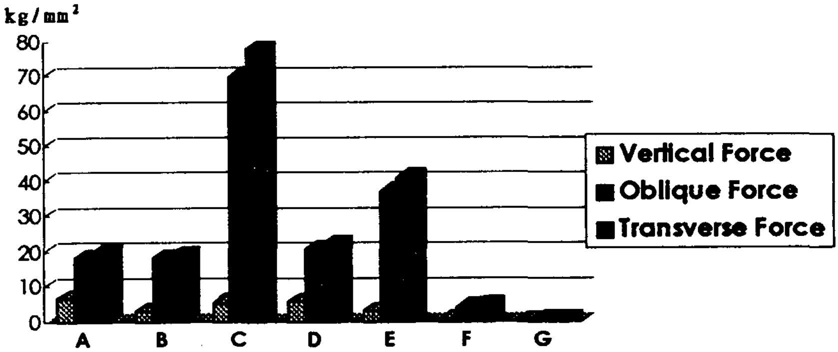
In the superstructure, stress was concentrated on the entire gold screw, and especially the neck of the gold screw between the head and threads showed the maximum value. The following stress value appeared in the neck of the abutment screw and the contact area between the abutment cylinder and the fixture. In the bone, similar stress distribution to the other models was observed, but the characteristic feature was the broader stress concentration area around the fixture apex than in the other models. Alike previous models, higher stress value was noticed under oblique and transverse force than under verti-

Table Ⅴ. The Von Mises Stresses in the Model 4(Kg/mm²)

position / force	A	B	C	D	E	F	G
vertical	6.557E+00	3.014E+00	5.412E+00	5.557E+00	3.000E+00	5.479E−01	1.191E−01
oblique	1.814E+01	1.792E+01	6.696E+01	2.068E+01	3.683E+01	4.069E+00	5.467E−01
transverse	1.972E+01	1.900E+01	7.736E+01	2.204E+01	4.079E+01	4.388E+00	5.229E−01

A : Gold screw
B : Gold cylinder
C : Abutment cylinder
D : Abutment screw
E : Fixture
F : Cortical bone
G : Cancellous bone

Fig. 8. The von Mises Stresses in Model 4.



cal force. Particulary, there was more stress concentration to the fixture under these two forces.

Ⅳ. Discussion

The treatments with osseointegrated implant achieved their firm position in dentistry as safe and stabilized ones. The early investigation about the osseointegrated implant focused on survival rates, functional aspects, biological reaction in the body and other subjects to restore patient's masticatory function[14,21,37,40-42,37]. The success criteria suggested by Alberktsson et al[2]. in 1986 demonstrated this fact. But, when the osseointegrated implant was used for partially edentulous patients and single tooth missed patients, the demand for more esthetic restorations increased. Initially, this was often accomplished with buccal flanges. Their use, however, created a potential for bacteral accumulation and could lessen the patient's ability to cleanse the area[7].

After that time, manufactures of dental implants produced various esthetic abutmnet systems, EsthetiCone abutment and MirusCone abutment. The manufacturer insisted that prosthesis, which uses esthetic abutmensts can place their margin subgingivally and have all the functions that standard abutment possesses. In the biological aspect, EsthetiCone abutment and MirusCone abutment with their collars at the base, continue the philosophy inherent in the conventional component of the Brånemark system that soft tissue interface can provide long-term success[1].

Stress distribution patterns also depended on the design, material, surface texture of the implant system. Therefore, when using EsthetiCone abument or MirusCone abutment which have different designs from standard abutment, it was evident that the mechanical analysis was necessary. This state was applied to a 5mm diameter fixture which has different design characteristics from the standard 3.75 mm diameter fixture. In this study, stress distribution patterns of four models were analyzed with the finite element method, which is one of the stress analysis methods. There were many studies on the stress distributions in the bone and implant when occlusal forces were simulated. Kim et al.[23] reported that there was a stress concentration on the neck of the implant and bone under horizontal loads. Borchers et al.[4] reported that high stress peaks which were calculated in the crestal region of the alveolar bone, especially with transverse loading, might cause bone resorption, connective tissue ingrowth, and subsequent implant failure. And reported that stress concentration were most distinct with the surroundings of the implant consisting of cancellous bone. Meijer et al.[33] also revealed that if a fixed bond between implant and bone was assumed, the extreme principal stresses were found in the crestal region around the neck of the implant. Lavernia et al.[30] assumed that trabecular representation for cancellous bone provided a more complete determination of stress state around an implant system when compared to the bulk representation. That is, the type of modeling used to represent cancellous bone had a substantial effect on the magnitude of the stresses in the cortical plates. However, the stress profiles for both cases were very similar.

Many investigators reported that stress in bone were concentrated on the alveolar crest and apex region with finite element analysis, photoelastic analysis, etc.,[4,15,25] when the implant placed in the bone was loaded. But the reports also stated the internal state of stresses in the implant were scarce. The characteristic feature of this study was to build the three-dimensional models in which individual components of each implant system were designed separately and were joined to investigate stress distribution in the internal structure of the implant system as well as in the bone.

In this study the maximum stress concentration occurred at the gold screw and at the gold cylinder in the superstructure. These fact were expected before the experiment because the gold screw and the gold cylinder were the first part bearing the direct loading, and especially the gold screw, made out of gold, a relatively weak material, has the smaller diameter than the other components. In the gold screw, the stresses concentrated on the neck. The reason was that the diameter of the neck portion was the smallest. In addition, the threaded portions distrbuted stresses to abutment screw[36]. This reason was also applied to abutment screw which was another component where stress concentrations occurred. In contact surface between the gold cylinder and the abutment cylinder, stress concentration occurred. The direct force transfered to the following component through these cylinders would explain these facts. In the fixture, maximum stress concentration occurred at the upper and middle thirds of the fixture, which contacted with the threaded portion of abutment screw. This was because the fixture distributed stress through the threads of the abutment screw. In the bone, stress concentrations occurred at the upper cortical layer and this results accorded with those of previous studies[4,26,33]. In the cancellous bone around fixture apex, stress concentrations occurred. Although the values were lower than those of the cortical bone, the results were also in accordance with those of the preceding report[36].

When comparing model 1 with model 2, model 2 showed much higher stress value in the overall superstructures. The design characteristics of the EsthetiCone abument system would explain this. Though, further study was needed to investigate the accurate behavior of occlusal forces, the break point of the implant component, and so on : this study carefully leads to the conclusion that EsthetiCone system might be used selectively in the posterior region of the dental arch where occlusal forces are intense[17,18]. The contact point of the gold cylinder is at the abutment collar in EsthetiCone system. So no side wall contact is created when the prosthesis is seated. The manufacturer states that this allowed transfer of occlusal forces in a manner similar to the stress distribution pattern designed in to conventional abutment. In this study, model 1 and model 2 showed similar stress distribution in the abutment, fixture, and bone.

When comparing model 2 to model 3, similar stress distributions were noticed, but overall higher stress values were observed in model 3. These results were expected because the MirusCone system has a diminished size in the individual part. But, MirusCone system will be used with reduced interarch space in clinical use. In this study the distance from the shoulder of a fixture to the top of a gold crown was the same in all models. The amount of force transfer is directly proportional to the height of the loading application from the crestal bone[32]. Therefore MirusCone system will not be so unfavorable from the result of this study with the clinical use. And the fact that the MirusCone system can be used in the situation with reduced vertical height, was the another advantage besides the esthetical advantage. Stresses tended to concentrate on the weakest component of the structure. For example, the component the diameter of which was the smallest, and the same result would developed when the material of the gold screw is changed to the stronger one. But this fact do not imply that more frequent fractures of the gold screw occur when MirusCone system is used. Further complementary study is needed about this opinion. The stress distribution patterns in model 3 were similar in model 1 and model 2. This is because the mechanical characteristics of MirusCone are the same as those of the EsthetiCone system ; horizontal seating of the gold cylinder. This horizontal seating allows for a more favorable distribution of the occlusal forces compared with a conical fitting.

There were many studies about the occlusal forces[5,9,10,17,18]. The stress concentrations were prominent under transverse force in this study. 20kg, the amount of force used seemed to the excessive in the lateral forces in terms of the previous studies[5,17]. But, because this study was not a quantitative one but a qualitative one, that is, the purpose was to investigate the differences of the stress distribution, this study seemed to be reasonable. Therefore, problems did not develop. Higher stress value was observed under transverse force, and this result accorded with the previous studies. Therefore, prosthesis supported with osseointegrated implant should be fabricated to induce little lateral force.

In model 4, the case where a fixture of 5mm diameter was used, there were no differences in stress distributions and values of the maximum stress in the superstructure from the other models. But there was higher stress value and broader stress distribution when it was compared to model 1. It was thought to be a buffering action of this wide diameter implant in force transfer. The fact that there were the broader stress distributions in the bone than in the model of 3.75 mm diameter revealed that the wide fixture was more favorable in the stress distribution to reduce transmitted stress than the standard fixture. But Rieger[36] said that the larger implant does not make better implants : increasing the overall implant size and increasing the bulkiness of the implant may not be of benefit after a certain point. Stresses transmitted to the bone around the implant were too low, and bone atrophy could have occurred. Though wide fixture is more favorable in mechanical aspect than the standard fixtre, factors other than diameter such as implant length, implant body configuration, number of implants, surface chemistry must be considered in implant selection[32].

Because the validity of the FEM results depends on the precision by which the geometry, material properties, interface condition, support and loading are in accordance with the physical reality[19], in this study it was tried to keep the precision in the above mentioned subjects as much as possible. However, finite element analysis can present only the mechanical aspects of the characteristics in the implant system. Though it may be concluded that EsthetiCone system and MirusCone system were unfavorable than standard system, and wide diameter fixture was more favorable than standard fixture mechanically in terms of the results of this study, long term clinical study, histologic study and other mechanical methods should be considered to predict the correct prognosis of the system.

V. Conclusions

In this study, the three-dimensional finite element method was used to evaluate the stress distributions of standard, EsthetiCone, and MirusCone abutment, which were connected to the fixtures of 3.75mm diameter, and the standard abutment connected to 5.0mm diameter fixture. The stress induced by vertical, oblique and horizontal forces loaded on the superstructures of them were compared and analyzed.

The results were as follows :

1. In all the models, stress concentrations occurred at the neck of the gold screw, gold cylinder, and at the abutment cylinder.
2. In the fixture of the every model, stress was concentrated on the upper two thirds of the fixture and the contact surface between the fixture and abutment cylinder.
3. In the bone, stress concentrations occurred at the upper cortical bone, and the cancellous bone area did not showed high stress peaks, but the stress value around the fixture apex was relatively high.
4. Among the three models with 3.75mm diameter fixture, standard abutment was the best in stress distribution, and MirusCone abutment was the worst.
5. Transverse force and oblique force brought about higher stress value than the vertical force did.
6. The stress value in the internal structure of the implant was much higher than in the bone.

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Explanations of Photographs

Von Mises Stress in Model 1 under vertical force
Photo. 1. von Mises stress in model 1
Photo. 2. von Mises stress in the Superstructure
Photo. 3. von Mises stress in the Bone
Photo. 4. von Mises stress in the Fixture

Vol Mises Stress in Model 1 under oblique force
Photo. 5. von Mises stress in model 1
Photo. 6. von Mises stress in the Superstructure
Photo. 7. von Mises stress in the Bone
Photo. 8. von Mises stress in the Fixture

Von Miese Stress in Model 1 under transverse force
Photo. 9. von Mises stress in model 1
Photo. 10. von Mises in the Superstructure
Photo. 11. von Mises stress in the bone
Photo. 12. von Mises stress in the Fixture

Von Mises Stress in Model 2 under vertical force
Photo. 13. von Mises stress in model 2
Photo. 14. von Mises stress in the Superstructure
Photo. 15. von Mises stress in the Bone
Photo. 16. von Mises Stress in The Fixture

Von Mises Stress in Model 2 under oblique force
Photo. 17. von Mises stress in model 2
Photo. 18. von Mises stress in the Superstructure
Photo. 19. von Mises stress in the Bone
Photo. 20. von Mises stress in Fixture

Von Mises Stress in Model 2 under transverse force
Photo. 21. von Mises stress in model 2
Photo. 22. von Mises stress in the Superstructure
Photo. 23. von Mises stress in the Bone
Photo. 24. von Mises stress in the Fixture

Von Miese Stress in Model 3 under vertical force
Photo. 25. von Miese stress in model 3
Photo. 26. von Miese stress in the Superstructure
Photo. 27. von Miese stress in the Bone
Photo. 28. von Miese stress in the Fixture

Von Mises Stress in Model 3 under oblique force
Photo. 29. von Mises stress in model 3
Photo. 30. von Mises stress in the Superstructure
Photo. 31. von Mises stress in the Bone
Photo. 32. von Mises stress in the Fixture

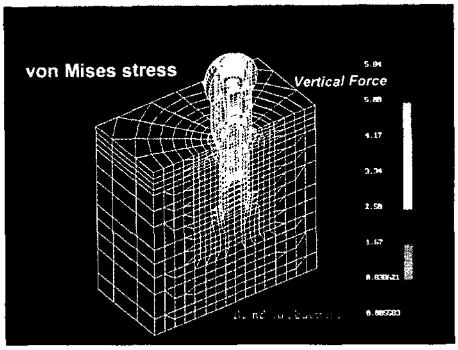
Von Mises Stress in Model 2 Under transverse force
Photo. 33. von Mises stress in model 3
Photo. 34. von Mises stress in the Superstructure
Photo. 35. von Mises stress in the Bone
Photo. 36. von Mises stress in the Fixture

Von Mises Stress in Model 4 under vertical force
Photo. 37. von Mises stress in model 4
Photo. 38. von Mises stress in the Superstructure
Photo. 39. von Mises stress in the Bone
Photo. 40. von Mises stress in Fixture

Von Mises Stress in Model 4 under oblique force
Photo. 41. von Mises stress in model 4
Photo. 42. von Mises stress in the Superstructure
Photo. 43. von Mises stress in the Bone
Photo. 44. von Mises stress in Fixture

Von Mises Stress in Model 4 under transverse force
Photo. 45. von Mises stress in model 4
Photo. 46. von Mises stress in the Superstructure
Photo. 47. von Mises stress in the Bone
Photo. 48. von Mises stress in Fixture

Photo. 1.



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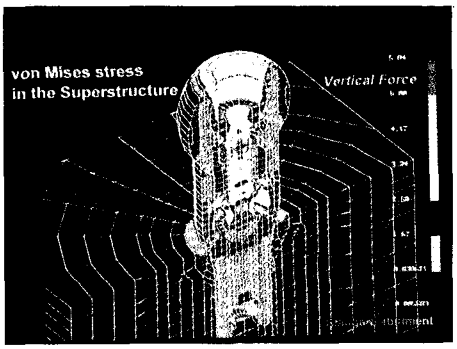

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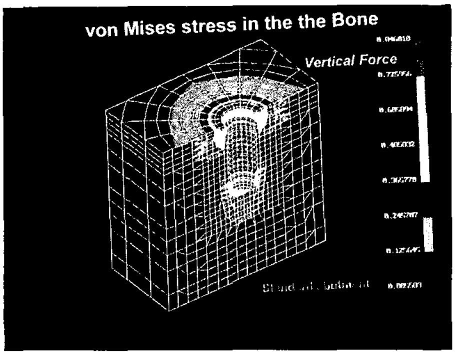

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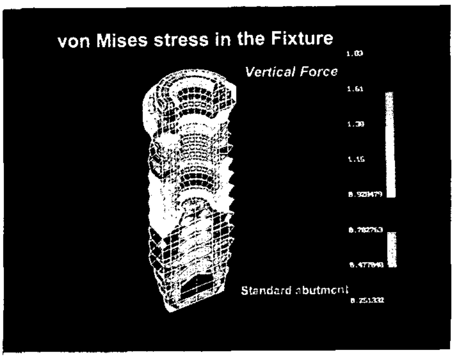

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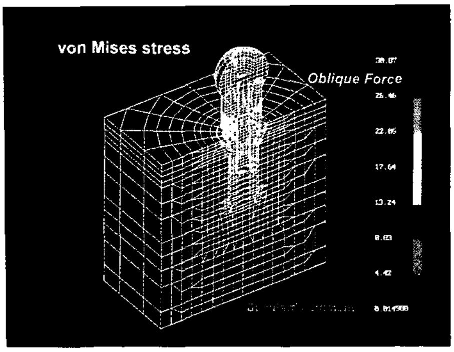

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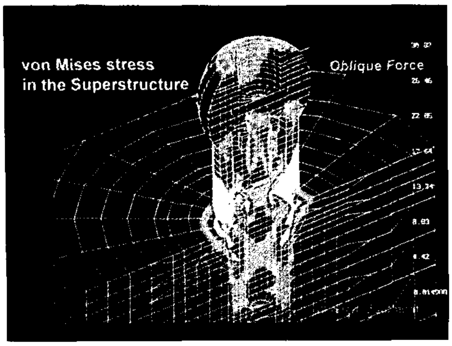

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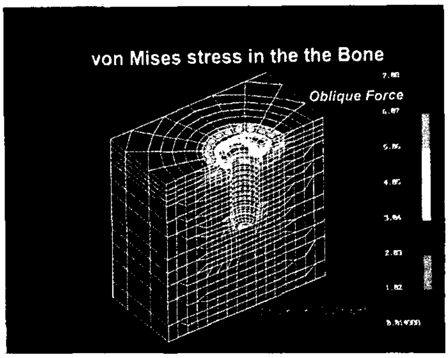

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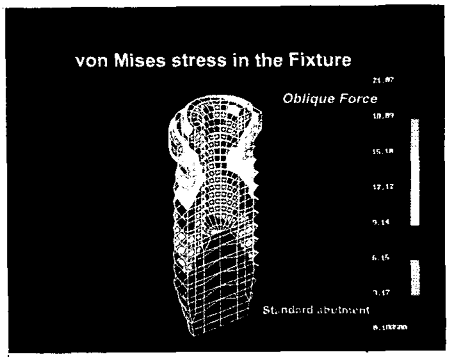

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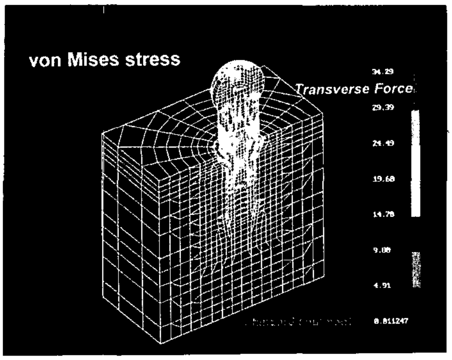

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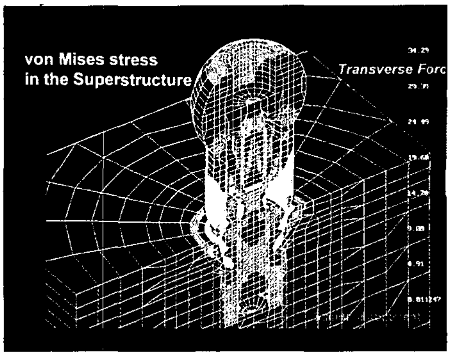

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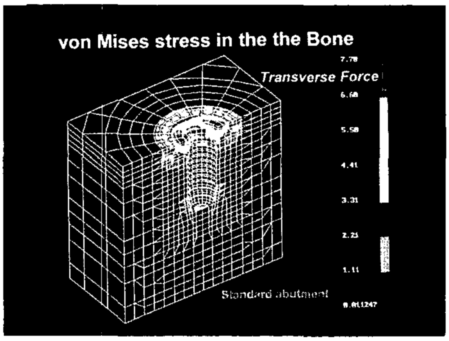

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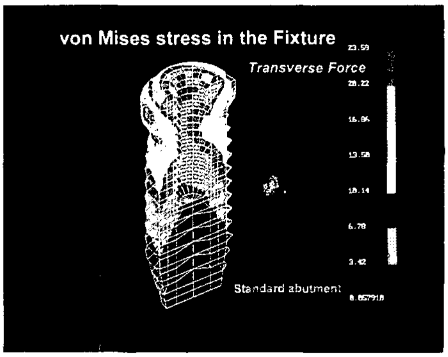

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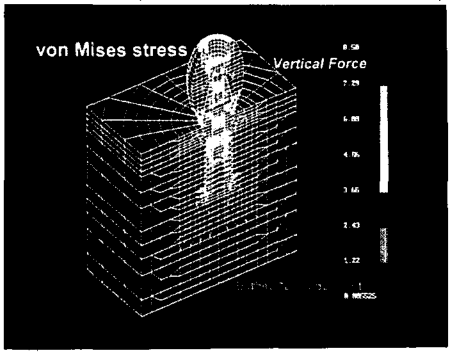

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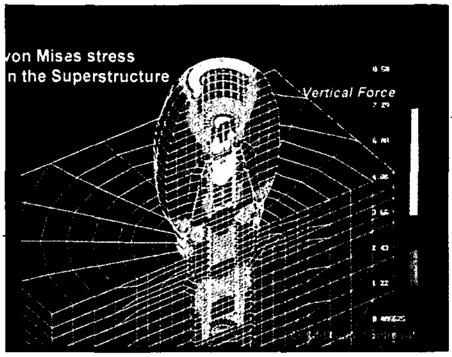

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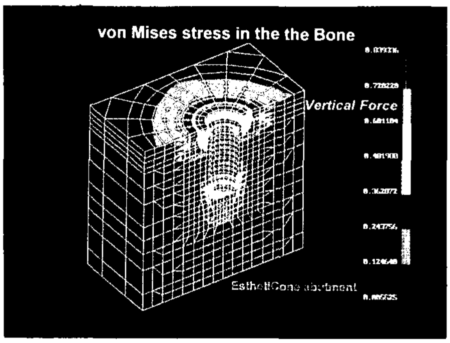

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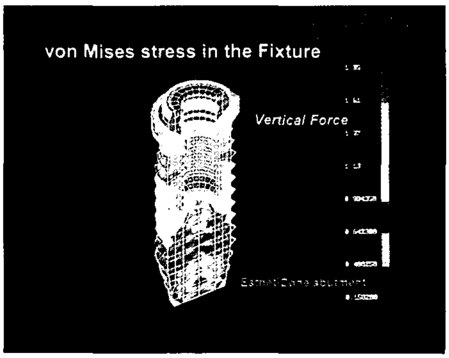

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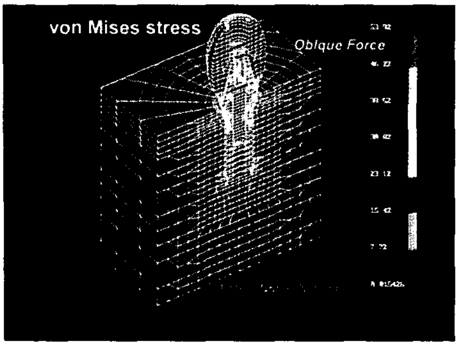

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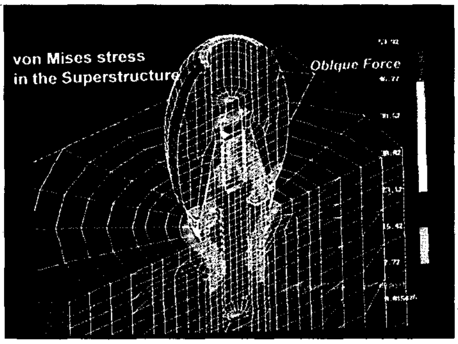

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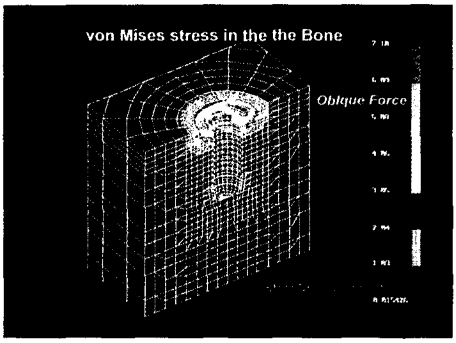

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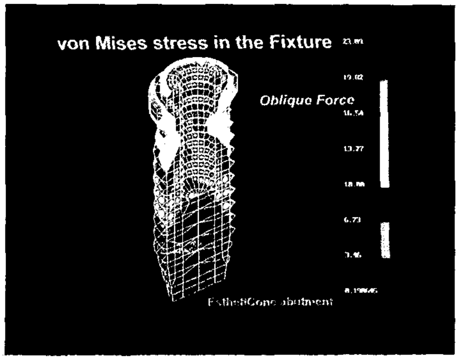

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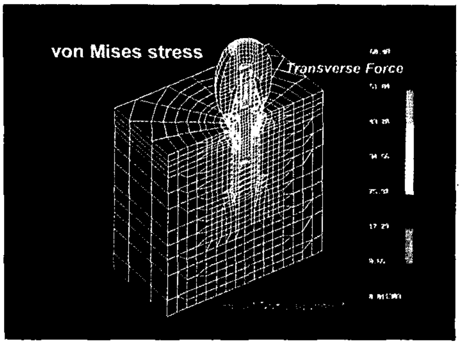

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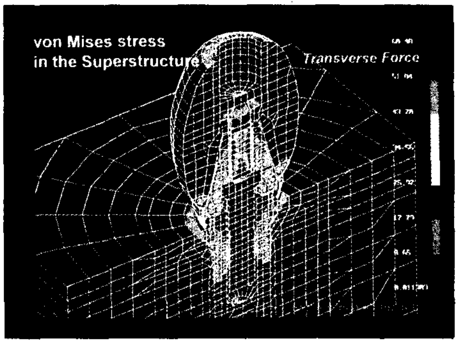

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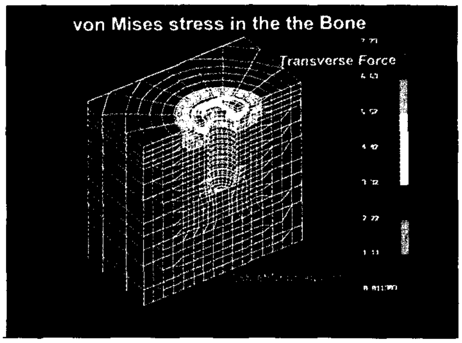

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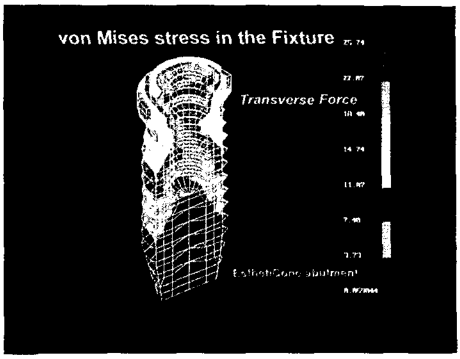

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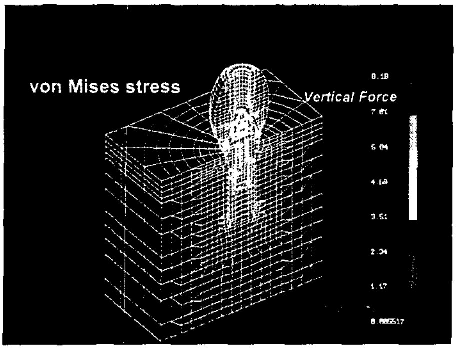

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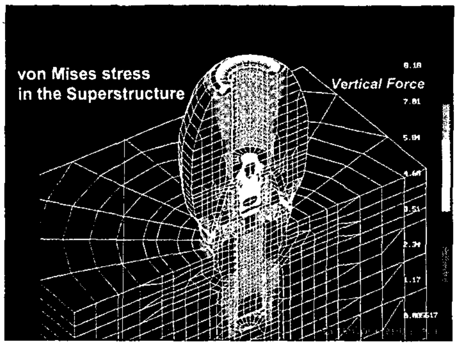

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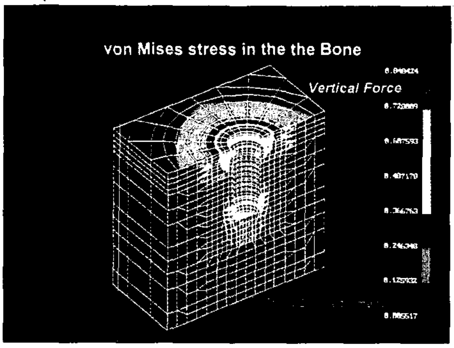

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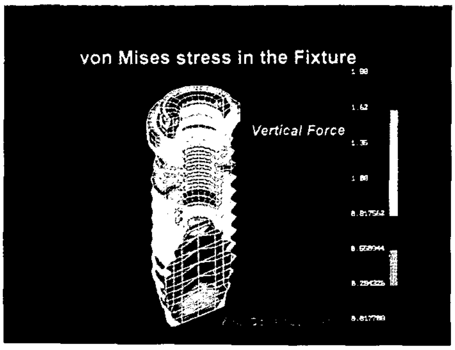

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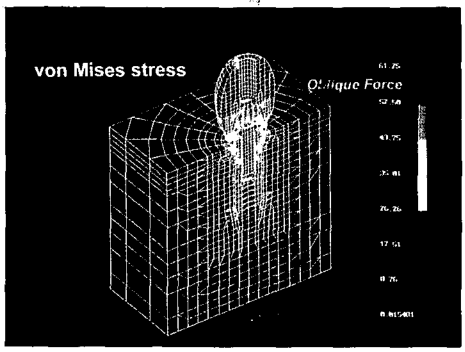

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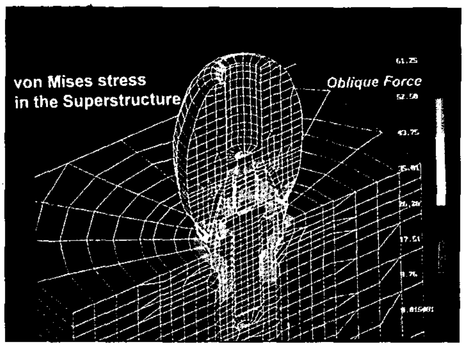

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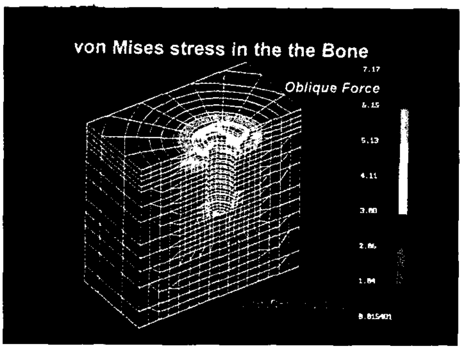

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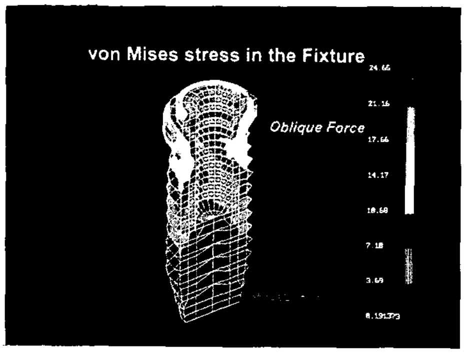

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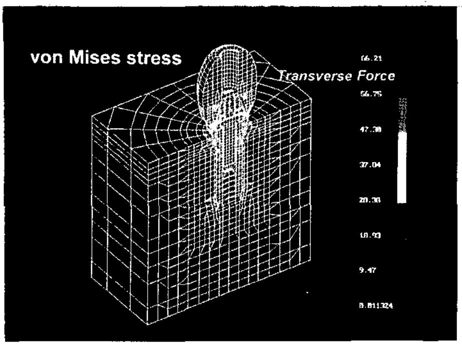

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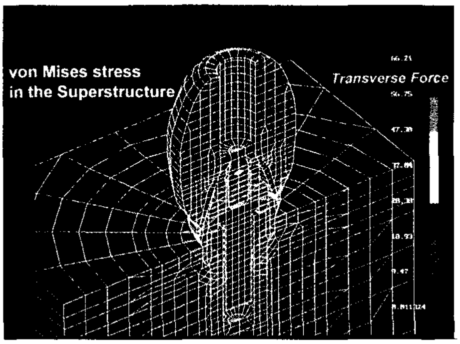

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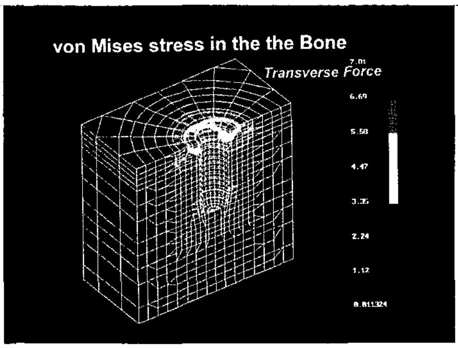

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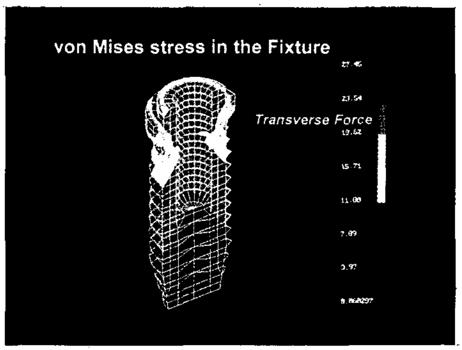

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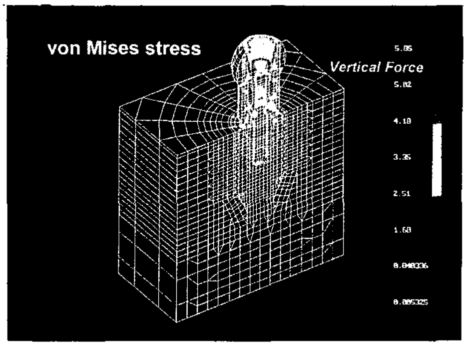

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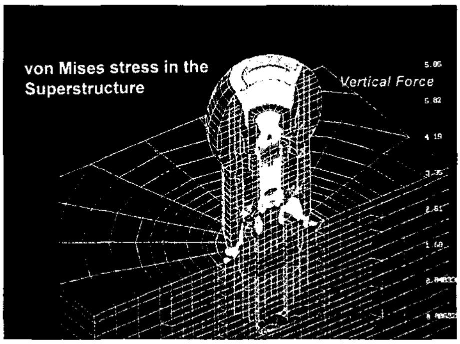

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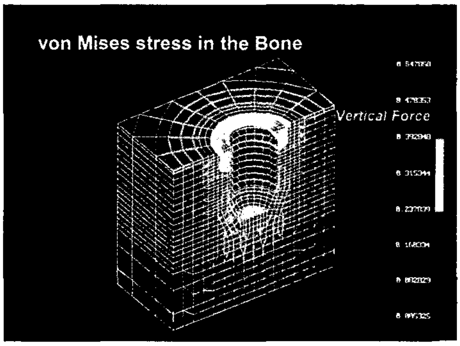

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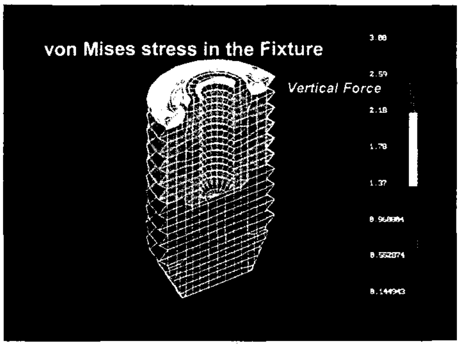

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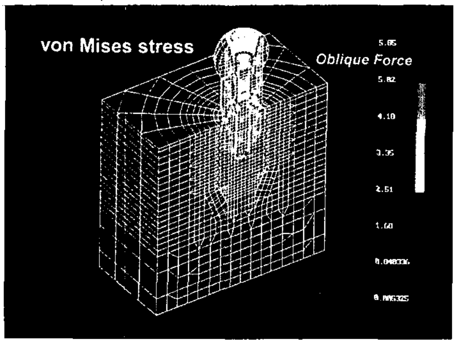

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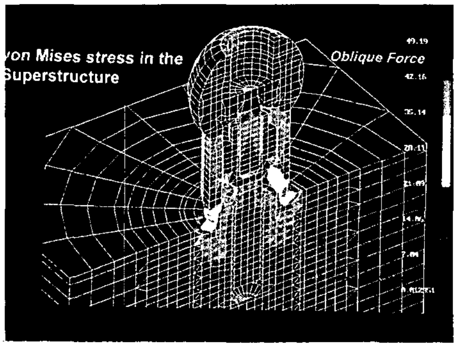

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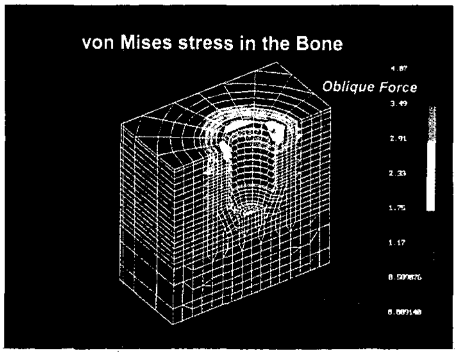

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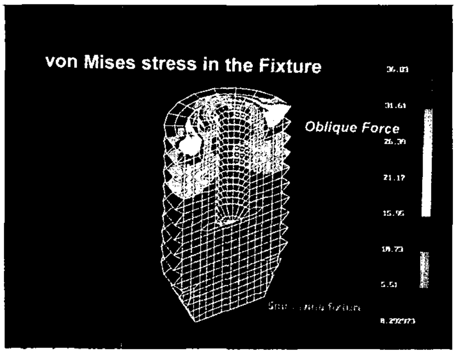

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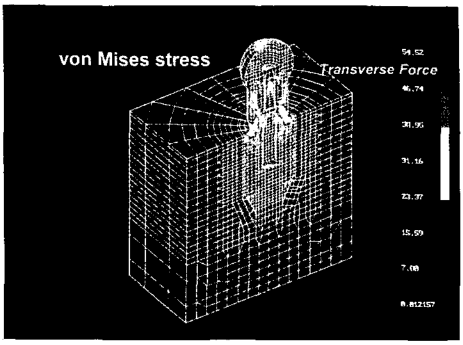

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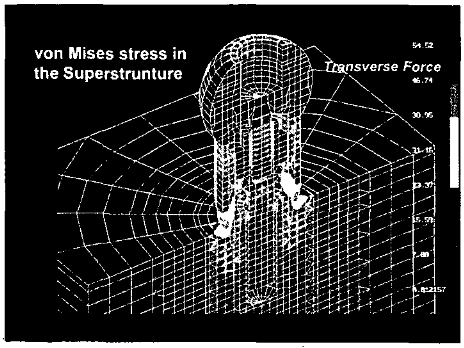

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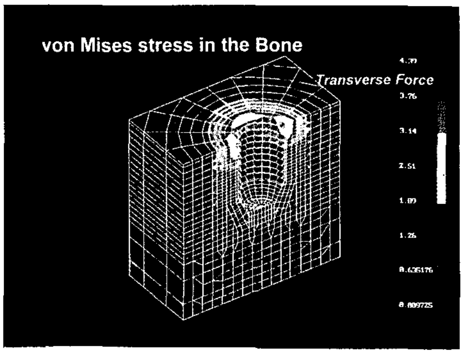

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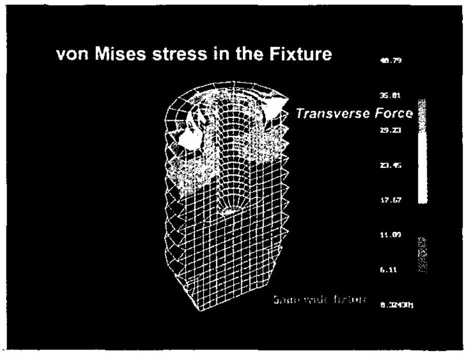

국문초록

각종 지대주 및 고정체 종류에 따른 골유착성 임플랜트의 응력 분포에 관한 삼차원 유한요소분석적 연구

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브로네마르크가 골유착성 임플랜트를 소개한 이래로, 현재 골유착성 임플랜트에 의한 치료는 안전하고 안정적인 방법으로 여겨지고 있다. 골유착성 임플랜트를 이용한 초기의 치료는 무치악 환자의 저작기능 회복에 중점을 두어 왔다. 그러나 현재는 환자와 시대의 요구에 따라서 심미성이 주요한 관심사가 되었다. 그래서 표준 지대주보다 더 심미적인 지대주 시스템들이 개발되었다.

다양한 직경의 임플랜트 고정체에 관한 임상가들의 요구에 의해 직경이 큰 고정체가 생산되기 시작했으며, 5mm의 직경을 갖는 고정체가 그 예이다.

골유착성 임플랜트를 사용하여 보철치료를 할 때, 골과 고정체의 계면은 보철물과 지대주에 가해지는 교합력을 인접골에 전달하게 되며, 이것은 계면에 생물학적인 반응을 야기할 수 있다. 임플랜트의 형태는 골흡수와 같은 바람직하지 않은 반응을 일으키지 않도록 고안되어야 하며, 임플랜트 자체가 교합력을 견딜 수 있어야 한다. 그러므로 골유착성 임플랜트 시스템을 임상에 사용하려고 할 때 이것의 생역학적 분석은 반드시 필요하다.

본 연구에서는 삼차원 유한요소분석적 방법을 사용하여 3.75mm직경을 갖는 고정체에 표준 지대주, 이세티콘 지대주, 마이러스콘 지대주를 연결한 모델과 5mm 직경을 갖는 고정체에 표준 지대주를 연결한 모델에 각각 수직하중, 경사하중, 수평하중을 가했을 때의 응력분포를 비교하였다.

본 연구의 결과는 다음과 같다.

1. 모든 모델에서 금나사의 경부, 금원주, 지대주에 응력의 집중이 일어났다.
2. 임플랜트 고정체에서는 고정체 상방 2/3, 그리고 지대주와 접촉하는 고정체 상면에서 응력의 집중이 관찰되었다.
3. 골에서는 상부 피질골에 응력의 집중이 관찰되었으며, 해면골에서는 두드러진 응력의 집중을 보인 부위는 없었으나 고정체의 근단부 주위 해면골에서의 응력값이 비교적 높았다.
4. 5mm 직경의 고정체를 사용하지 않은 모델 중에서, 표준 지대주를 사용한 경우가 가장 응력분산에 유리하였으며 마이러스콘 지대주를 사용한 경우가 가장 불리하였다.
5. 3가지 하중 조건하에서 수평하중과 경사하중의 경우가 수직하중의 경우보다 더 높은 응력값이 관찰되었다.
6. 응력값은 골에서보다 임플랜트 내부에서 훨씬 높았다.

주요어 : 유한요소분석법, 골유착성 임플랜트, 응력분포