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Investigation of the Effects of Abutment and Implant Length on Stability of Short Dental Implants

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Keywords

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Abstract: The use of dental implants to solve different problems in dentistry has been growing rapidly. The success rates of dental implants are also very important for patients. Depending on the bone level of patients, short dental implants are very popular and widely used by many dentists. Although many dentists are using short dental implants frequently, It can be guessed that there can be stability problems because of crown to implant ratios. In this study, it is aimed to find out the effects of dental implant and abutment lengths on stability of short dental implants. 3 different short dental implant design made with the use of Solidworks 2013. Abutment lengths were 3,5 mm, 4 mm, 4,5 mm, 5 mm and implant lengths were 5 mm, 6 mm, 7 mm for each model. Human mandible model is transferred from Computed Tomography. Then, each implant model is mounted to modeled mandible and Finite Element Analysis is performed for each model. In order to see the effects of implant number on stability, we performed same analysis by placing 4 implants to the mandible.

İmplant ve Abutment Boylarının Kısa Dental İmplantların Stabilitesi Üzerindeki Etkilerinin İncelenmesi

Anahtar Kelimeler

Kısa Dental İmplantlar
Sonlu Eleman Analizi
Abutment
Simülasyon
Tamamen Dişsiz Çene

Özet: Diş hekimliğinde bulunan farklı sorunları çözmek için dental implantların kullanımı hızla artmaktadır. Dental implantların başarı oranları da hastalar için oldukça önemlidir. Kısa dental implantlar, hastaların kemik seviyesine bağlı olarak çok popüler ve yaygın olarak pek çok diş hekimleri tarafından kullanılmaktadır. Birçok diş hekimi sık sık kısa diş implantları kullanmasına rağmen, implant-kron oranlarından dolayı stabilite sorunlarının gerçekleşebileceği tahmin edilebilir. Bu çalışmada, implant ve abutment uzunluklarının kısa dental implantlardaki stabilite üzerine etkilerinin incelenmesi amaçlanmıştır. Üç farklı kısa implant tasarımı Solidworks 2013 programı kullanılarak tasarlanmıştır. Her bir model için abutment uzunlukları 3,5 mm, 4 mm, 4,5 mm ve 5 mm, implant uzunlukları da 5 mm, 6 mm, 7 mm olarak tasarlanmıştır. Insan çene kemiği Bilgisayarlı tomografi görüntülerinden transfer edilmiştir. Her bir implant modeli çene kemiğine implante edilerek Sonlu Elemanlar Analiz yöntemiyle analiz edilmiştir. İmplant sayısının stabilite üzerindeki etkisini görmek amacıyla, tamamen dişsiz çeneye 4 adet implant yerleştirilerek analiz gerçekleştirilmiştir.

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1. Introduction

The implementation of dental implants for dental treatments has been growing and its use becoming safer than other kind of treatments if the correct indication is made for the patient. This safe solution, can be applied both for partially and totally edentulous maxilla and mandible, has been widely used with very high success rates (Henry, et al., 1996; Friberg, et al., 2000; Goodacre, 2003). However, success of dental implant treatment is affected by many factors such as implant-bone interface, location and geometry of dental implants, morphological properties of bone and the magnitude and type of loading. In addition, health factors such as smoking and bacterial environment that is caused by the patient is also a big problem for treatment success (Brunski, 1997; Brunski, et al., 2000; Lemons, 2004). Because of the loading is transferred from dental implant to bone, biomechanics of dental implants are having more importance on the bone around implant (Skalak, R., 1985).

It is known that diameter, length, location and surface design have influence on implant behaviours (Geng, et al., 2004; Verri, et al., 2007; Baggi, et al., 2008; Sa´nches-Garce´s, et al., 2010). In addition, connection systems between implant and abutment have also a big importance on dental implant biomechanics. The most used connection systems are external and internal hexagon (Sutter, et al., 1993; Binon, et al., 1994). Therefore, to understand the effectiveness and safety of using short dental implants, in comparison to their counterparts in regular length (10 mm or more), it is necessary to investigate the biomechanical behaviors of different implant parameters in SDIs in different bone qualities. Unfortunately, most of the literatures presented only conflicting clinical outcomes focusing on the differences of the survival rates between implants in short and regular lengths. Only few studies investigated the biomechanical effects of implant parameters of short dental implants. Most of the literatures discussed the biomechanical effects of implants in diameters of less than 6 mm and/or in lengths of more than 8 mm.

Specific conclusions still cannot be drawn due to the inconsistent outcomes, simplified geometry of numeric models for simulating real conditions, and lack of validation of the numeric models of previous biomechanical studies. The aim of this study is to investigate the biomechanical effects of varying length of a short-wide implant placed in the mandible by a three-dimensional (3D) FE analysis.

2. Materials and Methods

In this study, the 3-D model of human mandible was obtained by using CT images. To get the accurate geometry of the prosthesis and mandible, a computed tomography exam was carried out on the patient. 3D model of dental implants were designed with Solid Works 2013 for each kind of teeth models. In order to see the effects of mastication forces then we transferred 3D geometry to Ansys Workbench to make analysis on stress distributions. The geometry was meshed with Ansys Workbench Meshing tools to have realistic results.

The distribution of stress values on short dental implants were examined with finite element method. The dimensions of dental implants which were used in this study are presented in Table 1. . The loadings which were used as mastication forces, poisson ratios, elasticity modules, tensile strengths and other mechanical properties were taken from literature values.

Table 1. The dimensions of implants

	Implant Length (mm)			Abutment Length (mm)				Diameter (mm)
Model-1	5	6	7	3,5	4	4,5	5	5
Model-2	5	6	7	3,5	4	4,5	5	5
Model-3	5	6	7	3,5	4	4,5	5	5

Three different short dental implant models were designed with internal and external connection systems (Figure 1). Each short dental implant system is placed on a fully edentulous mandible. Then, static structural analyze is generated with 4 implant placed situation. The full model is meshed with advanced curvature on Ansys Workbench. After meshing process, loading locations, contact conditions and fixation points were defined on analyze interface. Modulus of Elasticity and Poisson ratio values of cortical bone, spongy bone, dental implants and crown are given in Table 2.

Table 2. Mechanical properties of materials

	Modulus of Elasticity (E)	Poisson's Ratio (v)
Titanium	110,000	0.35
Cortical Bone	14,700	0.30
Spongy Bone	1,370	0.30
Porcelain	68,900	0.28

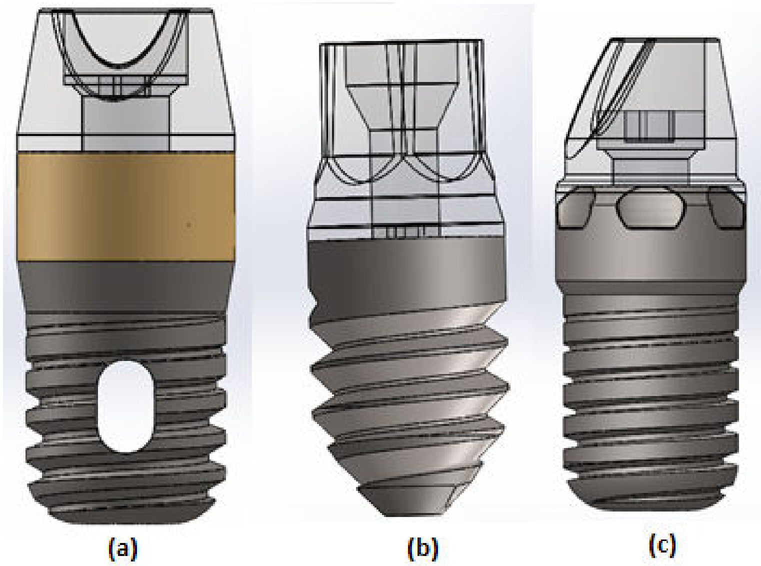


Figure 1. Three different dental implant models for internal and external connection systems

Finite element model of the mandible and dental implants can be seen in Figure 2. Three-dimensional finite element (FE) models were designed representing the mandible. The analysis were repeated for 3 different implant systems , 3 different implant length (5 mm, 6 mm, 7 mm) and 4 different abutment length (5 mm, 6 mm and 7 mm). In order to analyze effects of mastication forces to human mandible and implant fixture, we applied the loadings which were equal to 100 N for molars and 40 N for premolars. 2 molar and 2 premolar implants were located on mandible's right and left sides equally.

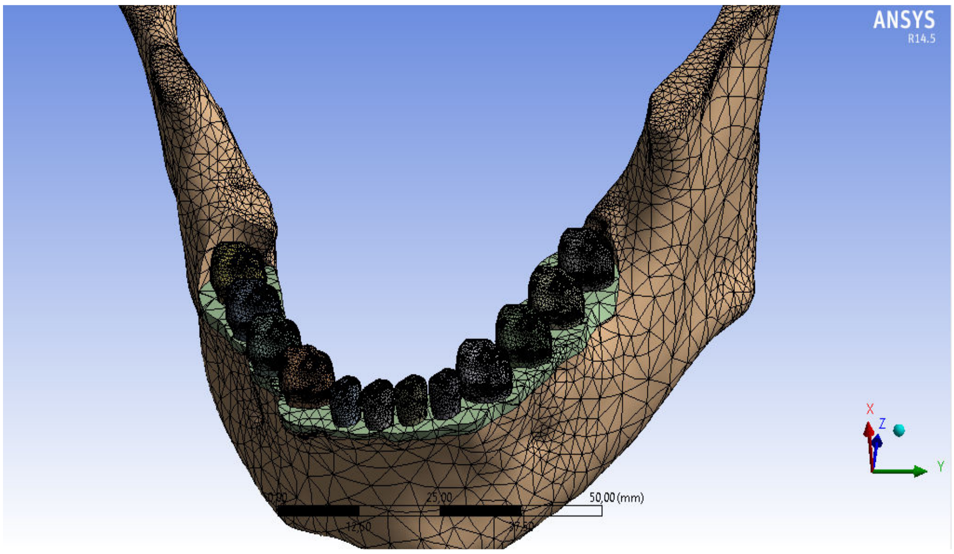


Figure 2. Full view of mandible and short dental implants with mesh

It was standardized only 5 mm for implants diameter in order not to create another variable and only evaluate the correlation between implant body length and dimension of implant prostheses; the implant prostheses were designed to be single screwed crowns, because it is assumed that in this non-splinted situation their biomechanical is most required, and it would generate higher stress.

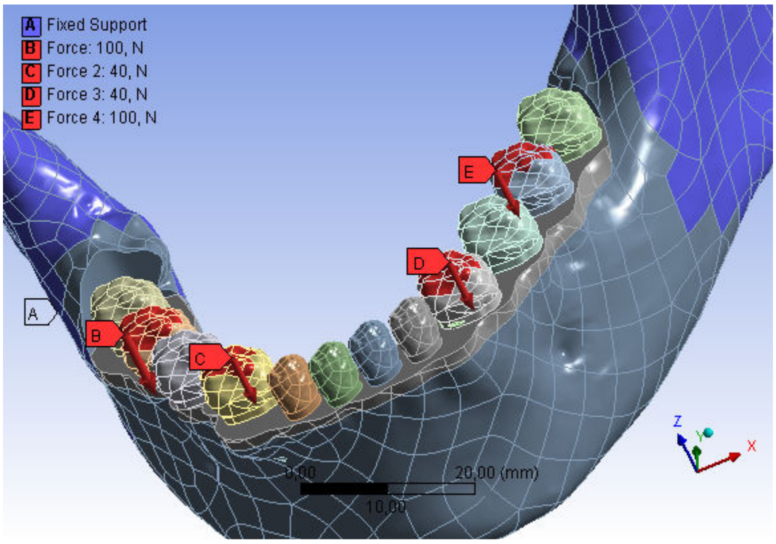
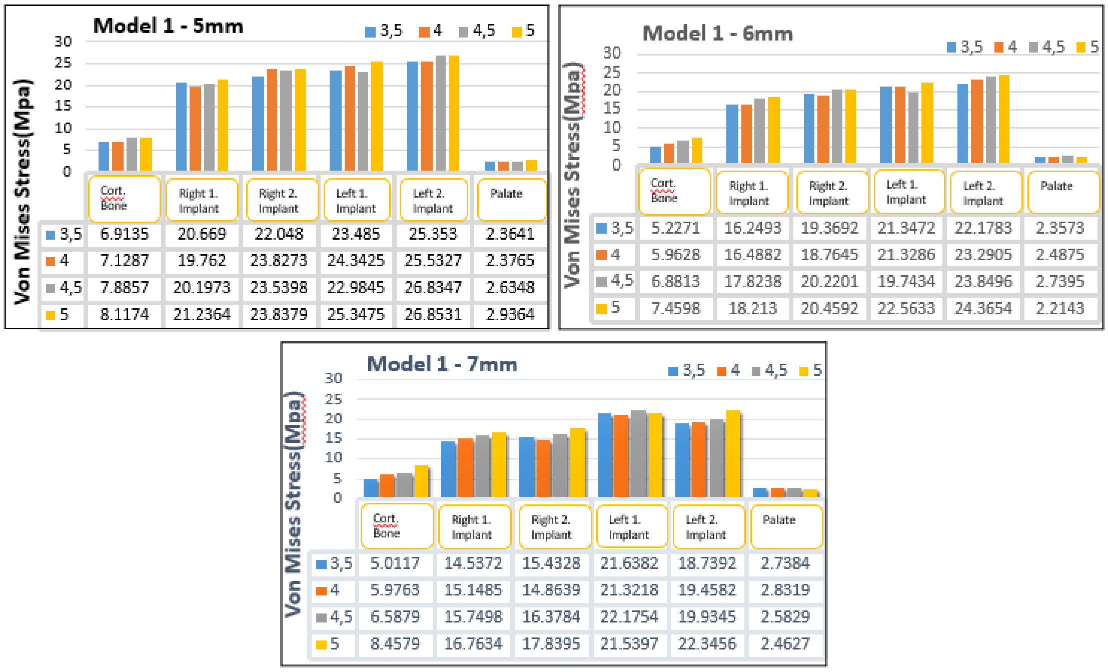


Figure 3. The view of implants, their loading locations and fixed support

3. Results

Stress levels were calculated using von Misses stress values (Ting, et al., 2010). Von Misses stresses are most commonly reported in FE analysis studies to summarize the overall stress state at a point (Ting, et al., 2010) and (Achour, et al., 2011). Deep analysis correlating implant length, diameter, cross-sectional area to side area, and design curves were obtained from this study. This analysis may help in selecting the suitable implant geometry to be used with patient jaw-bone conditions and limit of stresses can be withstand.

It can be seen also from Figure 4 that the stress values are decreasing when the implant length increase. On the other hand, when we compare the stress values for model-1 it is very clear that the von mises stress values are increasing with the increase on abutment length.



Model 1 - 5mm

	Cort. Bone	Right 1. Implant	Right 2. Implant	Left 1. Implant	Left 2. Implant	Palate
3,5	6.9135	20.669	22.048	23.485	25.353	2.3641
4	7.1287	19.762	23.8273	24.3425	25.5327	2.3765
4,5	7.8857	20.1973	23.5398	22.9845	26.8347	2.6348
5	8.1174	21.2364	23.8379	25.3475	26.8531	2.9364

Model 1 - 6mm

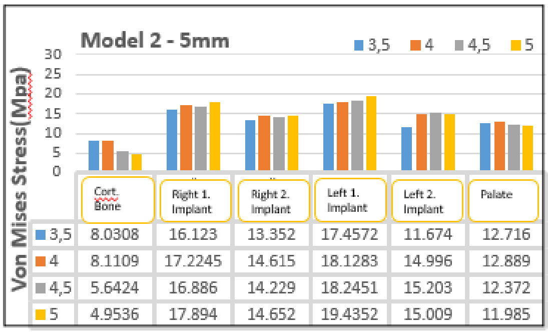
	Cort. Bone	Right 1. Implant	Right 2. Implant	Left 1. Implant	Left 2. Implant	Palate
3,5	5.2271	16.2493	19.3692	21.3472	22.1783	2.3573
4	5.9628	16.4882	18.7645	21.3286	23.2905	2.4875
4,5	6.8813	17.8238	20.2201	19.7434	23.8496	2.7395
5	7.4598	18.213	20.4592	22.5633	24.3654	2.2143

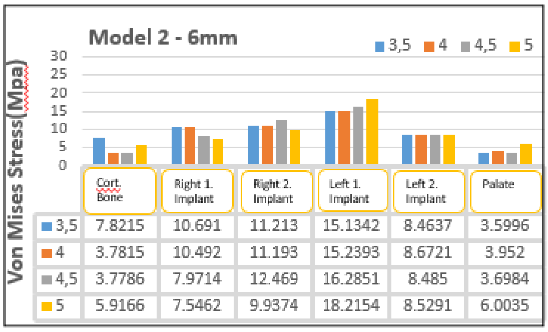
Model 1 - 7mm

	Cort. Bone	Right 1. Implant	Right 2. Implant	Left 1. Implant	Left 2. Implant	Palate
3,5	5.0117	14.5372	15.4328	21.6382	18.7392	2.7384
4	5.9763	15.1485	14.8639	21.3218	19.4582	2.8319
4,5	6.5879	15.7498	16.3784	22.1754	19.9345	2.5829
5	8.4579	16.7634	17.8395	21.5397	22.3456	2.4627

Figure 4. Results of analysis for model-1 according to implant lengths (5 mm, 6 mm and 7 mm), abutment lengths (3,5 mm, 4 mm, 4,5 mm, 5 mm) Cortical bone, palate and short dental implants (right-1. implant, right-2. Implant, left 1. implant, left 2. implant)

It can be seen also from Figure 5 that the similar trend is continuing on model-2. The stress values are increasing with implant length's increase and abutment length's decrease. But it is also clear that the average von mises stress values of model-2 is less than model-1.





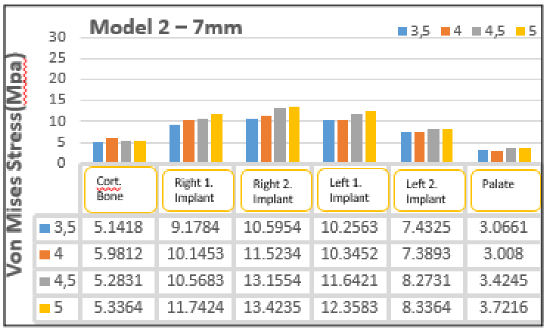
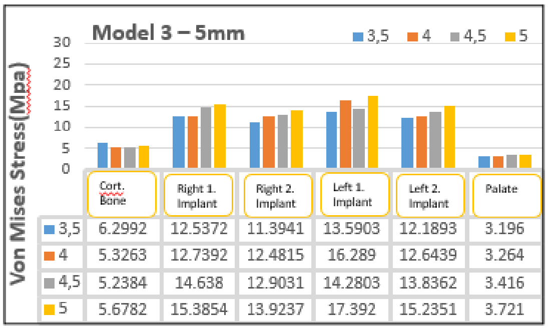
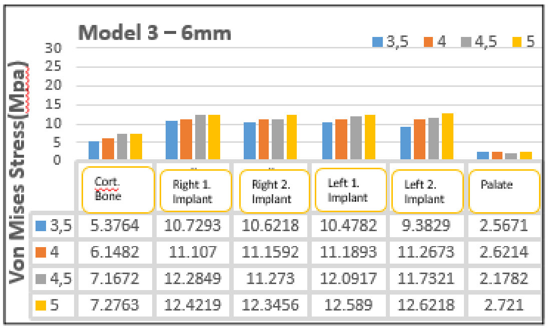


Figure 5. Results of analysis for model-2 according to implant lengths (5 mm, 6 mm and 7 mm), abutment lengths (3,5 mm, 4 mm, 4,5 mm, 5 mm) cortical bone, palate and short dental implants (right-1. implant, right-2. Implant, left 1. implant, left 2. implant)





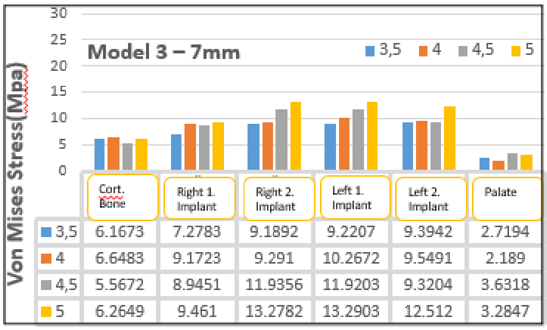


Figure 6. Results of analysis for model-3 according to implant lengths (5 mm, 6 mm and 7 mm), abutment lengths (3,5 mm, 4 mm, 4,5 mm, 5 mm) Cortical bone, palate and short dental implants (right-1. implant, right-2. Implant, left 1. implant, left 2. implant)

We observed that we have same trend on model-3 that we obtained with dimension changes. In addition, when we compare all three models according to average stress values obtained on short dental implants and cortical bones, the maximum stress values obtained from model-1 and the minimum stress values concentrated on model-3.

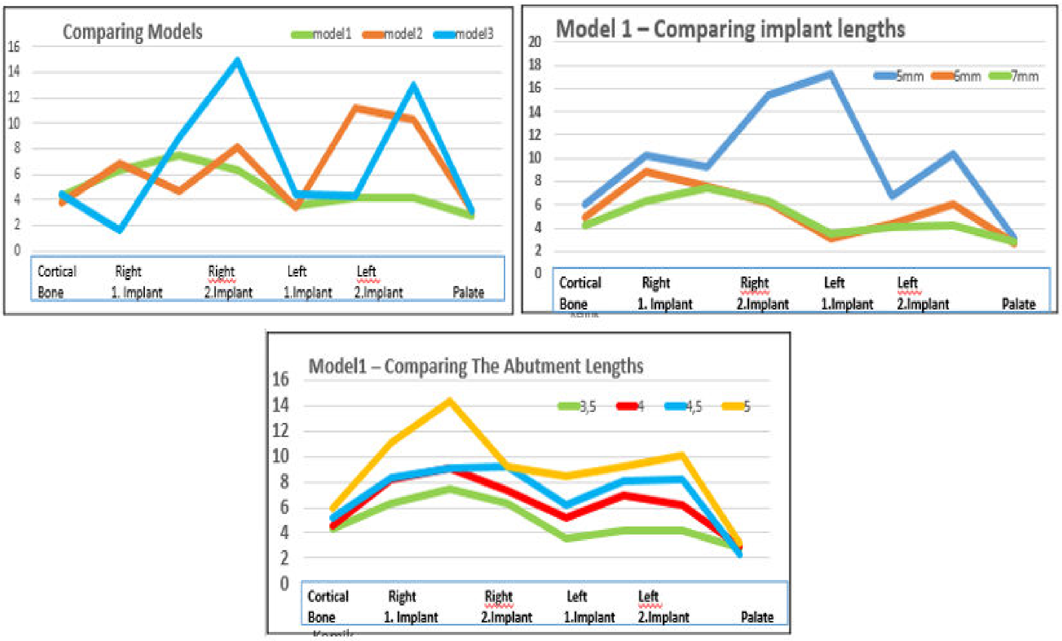


Figure 7. a) Comparison of 3 Models at most stable dental implant dimensions (implant length: 7 mm, abutment length: 3,5 mm) **b)** Comparison of implant lengths on model-1 (abutment length: 3,5 mm) **c)** Comparison of abutment lengths on model-1 (implant length: 7 mm)

When we evaluate all results, it is clearly observed that the increasing implant length is causing decrease on stress values and decreasing abutment length is also decreasing the stress values concentrated on dental implants and abutments. Also the stress values were increasing on the right side of mandible due to lack of bone density.

4. Discussion and Conclusion

For the loading conditions tested, the maximum stress values did not reach the yield strength of abutment and prosthetic screws of the implant/abutment joint systems evaluated. It is seem that the implant is durable all condition dynamic loading and overload at the end of work. Implant can be designed and studied in computer environment before it is implemented on the patient. This will save time for the design and prevent any permanent damage caused by miss-implementation of implant.

Many retrospective clinical studies shows high failure rates associated with short dental implants. (Ivanoff et al., 1999; Degidi et al., 2005). The von Mises Equivalent Stress (VMES) were evaluated, which provides a convenient representation of the stress situation (Geng, et al., 2004) in different groups. Quantitative comparisons were made between the different models to evaluate the generated stresses on the external surface of the implant bodies and their respective components.

The larger dimensions of the crowns, together with the shortest length of implants, caused more stresses at the surface of the implants (Marcelo, et al., 2013). Also it is clear on our result that these dimensions cause more stresses. It is observed that the crown-implant ratio is very important during short dental implant implementation. Because of moment effects on short implant crowns, there are larger stress values on both implants and mandible. In addition, pitch variation of screws also has a big importance on dental implant design. Short distance between pitches and aggressive design can cause more stress on dental implants. It can be seen from the results that the model-3 has the lowest stress concentration. Also the implant-abutment connection systems have caused these reductions on model-3's stress values. We can recommend to not to use short dental implants If It isn't so obligatory from the surgery view of implementation. Larger dimensions instead of short dental implants can be used in order to have a long-life dental implant operation. It can be suggested to use these kind of evaluation methods on critical surgeries before the implementation of short dental implants. On the other hand, the micro-movements between the implant and abutment has a big importance due to bone loses after 5-6 years. In order to eliminate these bone loses, the connection between implant and abutment must be done very carefully both by designer and dentist.

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