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COMPARISON OF SHORT DENTAL IMPLANTS UNDER DIFFERENT LOADING CONDITIONS AND LOCATIONS

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Anahtar Kelimeler
Short Dental Implants
Finite Element Analysis
Mandible
Simulation
Fully Edentulous

Abstract
Dental implant restoration has been widely accepted as one of the treatment modalities to replace missing teeth and to restore human masticatory function. The finite element method (FEM) has been a useful tool in studying the bone-to-implant interface under mechanical loading. The use of short dental implants are increased thanks to its advantages according to long dental implants when the quality of bone is lower. The aim of this study was to analyse the effects of implant diameter, length and loading conditions on short dental implants. A three dimensional (3D) model of short dental implants were made with different sizes and types. Dental implant designs were performed on Solidworks 2013. The mandible model is obtained from Computed Tomography then transferred to 3D model. Finite Element analysis is done by applying material properties, contact properties, physiological loading and boundary conditions with the use of Ansys Workbench.

FARKLI YÜKLEME ŞARTLARI VE YERLEŞİMLERDE KISA DENTAL İMPLANTLARIN KARŞILAŞTIRILMASI

Anahtar Kelimeler
Kısa Dental İmplantlar
Sonlu Eleman Analizi
Çene Kemiği
Simülasyon
Tamamen Dişsiz Çene

Özet
Dental implant restorasyonu, eksik dişlerin yerini dolduracak ve insan çiğneme fonksiyonunun yeniden kazanılmasını sağlayacak en yaygın tedavi yöntemlerinden biri olarak kabul edilmiştir. Sonlu elemanlar yöntemi (FEM) mekanik yük altında kemik-implant arayüz çalışmalarında yararlı bir araç olmuştur. Kısa dental implantların kullanımı, kemiğin kalitesi düşük olduğunda uzun dental implantlara göre daha avantajlı olduğu için artmıştır. Bu çalışma, kısa dental implantlarda implant çapı, uzunluğu ve yükleme koşullarının etkilerinin görülmesi amacıyla gerçekleştirilmiştir. Kısa dental implantların üç boyutlu (3D) modeli farklı boyutlarda ve farklı dizaynlarda yapılmıştır. Dental implantların tasarımları Solidworks 2013 programıyla oluşturulmuştur. Üç boyutlu çene kemiği modeli bilgisayarlı tomografiyle elde edilmiştir. Sonlu eleman analizleri ise malzeme özellikleri, temas özellikleri, fizyolojik yükleme ve sınır şartları girilerek Ansys Workbench programıyla yapılmıştır.

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1. Introduction

The interaction between implants and their adjacent structures is very important for the rehabilitation success, because the understanding and respect to their biomechanical questions are fundamental to the proper functioning of the implants and implant-supported prostheses. Moreover, factors of fundamental importance as the bone volume and implant body length, bone density and implant surface area and functional loads applied should also be considered [Skalak, 1985: Brunski, 1997: Brunski, et al. 2000]. In order to promote an adequate and effective osseointegration.

To make this behavior clearer and that its applicability could be made more secure clinically, finite element analysis (FEA) allows better understanding of how the transmission and distribution of stresses occurs on the implants. Bioengineering studies have been important to understand the biomechanics and behavior of osseointegrated implants and prosthesis.

Thus, there are a number of factors that are critical about the biomechanical behavior of the whole system implant and implant prosthesis. The use of short implants has been studied [Friberg, 2000], although little is known about their behavior to demands associated with increased proportions implant prostheses, with occlusal oblique loads as it actually occurs in the oral cavity. In addition, external and internal hexagonal connections have also been fully explored, but the morse taper implant is still unknown in many aspects of functioning.

Therefore, it may be beneficial to use short dental implants with limited height, which are usually at mandibles. Yet, clinical studies, mostly retrospective, showed higher failure rates associated short dental implants[Geng, 2004; Verri, 2007]. While some other clinical studies reported comparable survival rates of short dental implants and implants of regular length [Baggi, et al. 2008; Sa´nches-Garce´s, et al. 2010].

In spite of all clinical results biomechanical questions often arise concerning load distribution on dental implants and bone [Skalak, 1985; Brunski, 1997] as well as the resulting stress and strain fields for each oral function (as for instance during mastication action). The purpose of the present study is to investigate the static behavior of dental implants numerically. A detailed model of the mandible, implant and other components are designed to obtain reliable results. And then this 3D model is transferred to ANSYS for evaluating stress distributions on dental implant.

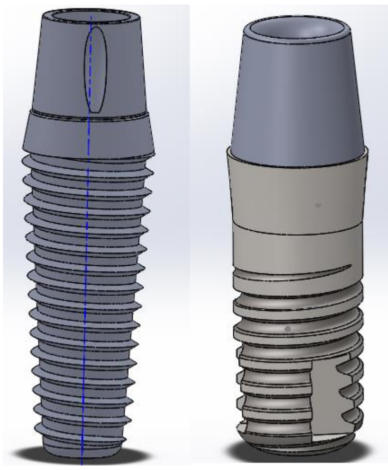
2. Materials and Methods

The human mandible model was generated with Next Engine laser scanner and all dental implant and crown models were designed with Solidworks 2013. We tried to obtain a full mandible in order to have more realistic results. It was seen on many studies that the details of mandible weren't taken into consideration. But it is very important to see the difference of bone qualities at different regions of human mandible. All models transferred to Ansys Workbench finite element analyze software to see the effects of mastication forces on each cases.

The dimensions of short and regular dental implants are given in Table 1. Two different dental implants are modeled to compare in 3 different cases. By this way, we observed the stress differences with implementation of short and regular dental implants at different locations. We limited the dimension of short dental implant at 8 mm to have an average short dental implant and 13 mm for regular dental implant

Table.1 The dimensions of dental implants

	Implant Length (mm)	Abutment Length (mm)	Diamet er (mm)
Short Implant (Model-1)	8	4	3,5
Regular Implant (Model-2)	13	5,5	6



(a) (b)

Figure 1. a) Short dental implant and **b)** regular dental implant model

Dental implants are implemented as 3 different cases: in first case, we applied 2 short dental implants on premolar and 4 regular dental implants on molar, in other cases, we applied fully short dental implants and fully regular dental implants in order to see differences on them. In addition, we applied axial and oblique forces to compare the effects of oblique forces. On the other hand, type-3 and type-4 bone qualities were applied to see the effects of bone qualities on dental implant applications. The model of short dental implant and regular dental implant can be seen in Figure 1.

All values as elasticity modulus, passion ratios and other mechanical properties were defined depending on previous studies. The mechanical properties of materials 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

The FEA model of mandible, short and regular dental implants can be seen in Figure 2.

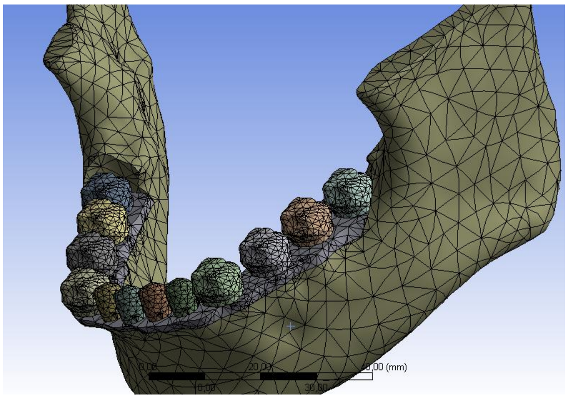


Figure 2. Full view of mandible and short dental implants with mesh

The analyses are done for 3 different implant placements, 2 different loading conditions and 2 different bone types. The forces as mastication forces (100 N) were applied on dental implant prosthesis for both axial and oblique loading conditions. The loading locations, magnitudes and fixed support points can be seen in Figure 3.

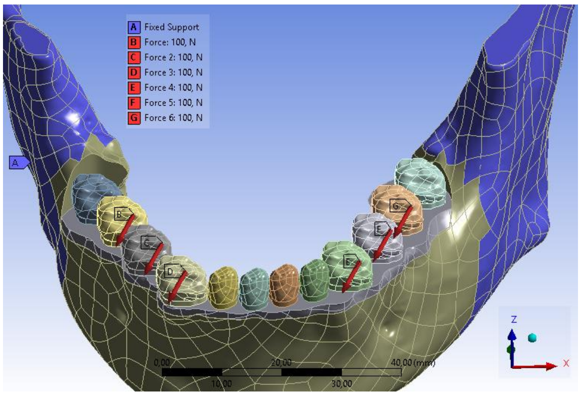


Figure 3. The view of implants, their loading locations and fixed support

Static structural analyze were conducted with the use of Ansys workbench software in order to obtain all results for each parts accurately.

3. Results

The aim of this study is to investigate the effect of different bone qualities, implant dimensions, loading locations and conditions on dental implants. According to the obtained results, were made graphics that are expressing the values of the biggest areas of stress concentration. The results were defined for 3 different dental implant implementation, axial and oblique loading conditions and type-3, type-4 bone types. The von mises stress values were reported for each dental implants, cortical bone and crowns for all conditions (Table 3).

Table 3. Results of My Implants' Von Mises Values

		Cortical Bone (MPa)	Right-1 (MPa)	Right-2 (MPa)	Right-3 (MPa)	Left-1 (MPa)	Left-2 (MPa)	Left-3 (MPa)	Crown (MPa)
Case-1 6 Regular	Oblique Type-4	17,642	76,143	79,287	96,28	81,723	52,913	43,218	120,12
	Oblique Type-3	14,762	75,743	77,128	91,934	77,812	51,192	42,613	128,16
	Axial Type-4	7,534	42,198	32,623	38,913	52,942	41,72	31,912	85,812
	Axial Type-3	7,312	38,814	28,956	35,126	47,312	37,632	26,017	78,936
Case-2 2 short 4 Regular	Oblique Type-4	25,835	93,953	99,405	111,7	85,083	59,143	47,533	137,4
	Oblique Type-3	22,944	104,65	111,36	125,5	96,746	67,179	47,53	146,57
	Axial Type-4	10,211	55,058	42,597	43,357	60,367	42,979	37,487	92,892
	Axial Type-3	10,318	50,731	37,763	39,414	53,003	37,878	37,486	87,372
		Cortical Bone (MPa)	Right-1 (MPa)	Right-2 (MPa)	Right-3 (MPa)	Left-1 (MPa)	Left-2 (MPa)	Left-3 (MPa)	Crown (MPa)

Case-3 6 short	**Oblique Type-4**	66,907	366,03	335,56	260,09	695,59	253,77	241,02	139,94
	Oblique Type-3	63,949	336,25	309,09	260,08	669,58	253,76	241	127,24
	Axial Type-4	25,89	203,29	102,61	81,126	78,771	76,507	73,651	88,742
	Axial Type-3	26,229	76,96	94,284	184,98	74,809	71,926	69,686	81,344

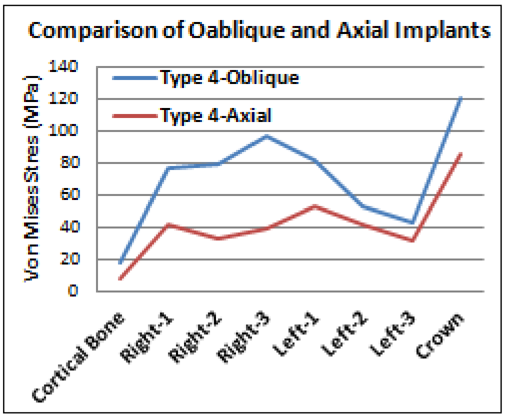


Figure 5. The comparison of stress values according to oblique and axial loading types

The comparison graph of loading conditions for axial and oblique (30°) can be seen from Figure 5. It is very clear that oblique forces have more stress values than axial forces for all three cases. Both oblique and axial loading conditions were caused more stress on fully short dental implant case. The lowest stress values were obtained from the case in which we have all 6 dental implants at regular length.

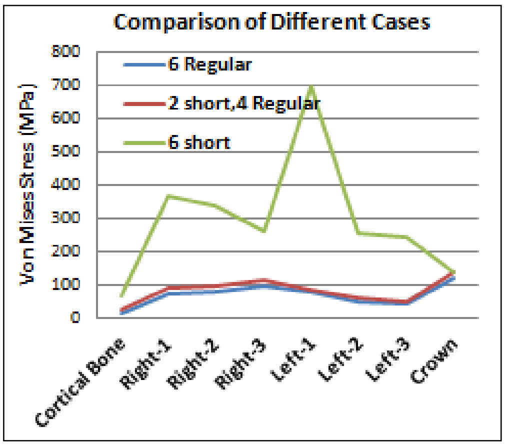


Figure 6. The comparison of 3 different cases for type-4 and axial loading condition.

When we compare all 3 cases for type-4 bone type and axial loading conditions on which we obtained highest stress values, it is very clear that the stress values decrease on case-1. On the other hand, the stress values were increasing with addition of short dental implants on case-2 and finally we obtained highest stress values on case-3 that we applied 6 short dental implants on our mandible model.

4. Discussion and Conclusion

Finite element modeling is used in this study has many limitations when we think about the response of biologic systems to applied loads, as do all modeling systems, including photoelastic analysis and strain gauge measurement [Ochiai, 2004: Celik, 2007]. However, the findings of this kind of study may provide a broader understanding about the potential stress concentration locations, and a better elucidation about the biomechanics of implantology.

Sotto-Maior et al. concluded that C/I ratio contributes to the stress concentrations [Sotto-Maior, 2005]. Similar results were reported by Sutpideler et al. [Sutpideler, 2004], who indicated that an increased C/I ratio leads to higher stresses. In the present study the same findings were observed, since the greater crown height together with the shortest length of implants caused more stresses at the surface of the implant bodies.

The use of short dental implant on fully edentulous mandible increases the stress values that is concentrated on implant-mandible and implant-abutment connection points. From the simulations obtained it can be observed that the bone qualities also effects significantly on stress distribution. Type-4 bone had more stress values than the type-3 bone as expected.

When we compare the results according to axial and oblique loading, it is very clear that higher stress values obtained on oblique loading conditions. The most significant stress increasing were realized on right front sides of our mandible due to the lack of bone density around this region. The use of short dental implant cause more stress values when we compare with regular dental implants. Also crown-implant ratio must be taken into consideration. In addition to dental implant dimension, also implant-abutment connection type and design has critical role on decrease of stress values and micro-movements aroud the implant neck and implant-bone connection region.

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Conflict of Interest

No conflict of interest was declared by the authors.

5. References

Baggi. L.. Cappelloni, I., Girolamo, M.D., Maceri, F., Vairo, G., 2008. The Influence of Implant Diameter and Length on Stress Distribution of Osseointegrated Implants Related to Crestal Bone Geometry: a Three Dimensional Finite Element Analysis. J Prosthet Dent; 100:422–31.

Binon, P.P., Sutter, F., Beaty, K., Brusnki, J., Gulbransen, H., Weiner, R., 1994. The Role of Screws in Implant Systems. Int J Oral Maxillofac Implants; 9(Supplement): 48–63.

Brunski, J. B., 1997. “Biomechanics of Dental Implants.” in Implants in Dentistry, pp, 63–71.

Brunski, J.B., Puleo, D.A., Nanci, A., 2000. “Biomaterials and Biomechanics of Oral and Maxillofacial Implants: Current Status and Future Developments.” International Journal of Oral and Maxillofacial Implants. Vo, 15. no. 1. pp. 15–46.

Celik, G., Uludag, B., 2007. Photoelastic Stress Analysis of Various Retention Mechanisms on 3-implant-retained Mandibular Overdentures. J Prosthet Dent; 97:229–35.

Friberg, B., Grondahl, K., Lekholm, U., Branemark, P.I., 2000. Long-term Follow-up of Severely Atrophic Edentulous Mandibles Reconstructed with Short Branemark implants. Clin Implant Dent Relat Res; 2:184–9.

Geng, J.P., Ma, Q.S., Xu, W., Tan, K.B.C., Liu, G.R., 2004. Finite ElementAanalysis of Four Thread-form Configurations in a Stepped Screw Implant. J Oral Rehabil; 31:233–9.

Goodacre, C.J., Bernal, G., Rungcharassaeng, K., Kan, J.Y.K., 2003. Clinical Complications with Implants and Implant Prostheses. J Prosthet Dent; 90:121–32.

Henry, P.J., Laney, W.R., Jemt, T., Harris, D., Krogh, P.H., Polizzi, G., 1996. Osseointegrated Implants for Single-tooth Replacement: a Prospective 5-year Multicenter Study. Int J Oral Maxillofac Implant; 11:450–5.

Lemons, J.E., 2004. “Biomaterials, Biomechanics, Tissue Healing. and Immediate-function Dental Implants.” The Journal of Oral Implantology. vol. 30. no. 5. pp. 318–324.

Ochiai, K.T., Willians, B.H., Hojo, S., Nishimura, R., Caputo, A.A., 2004. Photoelastic Analysis of the Effect of Palatal Support on Various Implant-supported Overdenture Designs. J Prosthet Dent; 91:421–7.

Sa´nches-Garce´s, M.A., Costa-Berenguer. X., Gay-Escoda, C., 2010. Short Implants: A Descriptive Study of 273 Implants. Clin Implant Dent Relat Res.

Skalak, R., 1985. Aspects of Biomechanical Considerations. In: Branemark P-I. Zarb GA. Albreksson T. eds. Tissueintegrated Prostheses – Osseointegration in Clinical Dentistry. Chicago. IL: Quintessence: 117–128.

Sotto-Maior, B.S., Senna, P.M., Silva, W.J., Rocha, E.P., Cury, A.A.D.B., 2012. Influence of Crown-to-Implant Ratio. Retention System. Restorative Material. And Occlusal Loading on Stress Concentrations in Single Short Implants. Int J Oral Maxillofac Implants; 27:13–8.

Sutpideler, M., Eckert, S.E., Zobitz, M., An, K.N., 2004. Finite Element Analysis of Effect of Prosthesis Height, Angle of Force Application, and Implant Offset on Supporting Bone. Int J Oral Maxillofac Implants; 19(6):819-25.

Sutter. F., Weber. H., Sorensen. J., 1993. The New Restorative Concept of the ITI Dental Implant System: Design and Engineering. Int J Periodontics Restorative Dent; 13:409–31.

Verri, F.R., Pellizzer. E.P., Rocha. E.P., Pereira, J.A., 2007. Influence of Length and Diameter of Implants Associated with Distal Extension Removable Partial Dentures. Implant Dent; 16:270–6.