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Biomechanical evaluation and comparison of the stress distribution at bone implant interface of one piece and two-piece dental implants: 3-D Finite Elemental Study

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Abstract

Purpose: The conventional two-piece implant design renders with a weak link in the junction of implant body and abutment. In this study 3-D Finite Elemental Analysis (FEA) is used to simulate and evaluate the stress distribution at bone–implant interface of one-piece and two-piece dental implants, with the aim of understanding the biomechanical mechanisms.

Materials and Methods: Four experimental artificial jawbone FE models were prepared for one-piece-3.5mm and two-piece-4.3mm diameter implant systems with 10mm length. In FE simulations, the distribution of Von-Mises stresses in the implant and bone were statistically analysed.

Results: There is significance difference of the Von-Mises stresses distribution observed between all the models.

Conclusion: The overall stress is increased in two-piece dental implants compared to the one-piece dental implants and the stresses on Cancellous and Cortical bone are reduced with increase in the diameter of implant.

Keywords: One–piece, Two-piece, Von-Mises stress.

Introduction

A new era of oral rehabilitation began when Brånemark and associates introduced the concept of osseointegration as a predictable method for anchoring implants for the support of dental prosthesis.[1] Implant dentistry requires a blend of diagnostic, treatment planning, prosthetic and maintenance skills in order to achieve maximum success. The goal of implant dentistry is to restore the normal contour, comfort, function, aesthetics, speech and health for the patient.[2] The use of dental implants to replace the natural tooth has become a common practice in the contemporary restorative and surgical dentistry.[3] Biomechanical factors play a substantial role in implant success or failure. The occlusal forces induce stresses and strains within the implant-prosthesis complex; affect the bone remodelling process around implants. To achieve optimized biomechanical conditions for implant-supported prostheses, conscientious consideration of the biomechanical factors that influence prosthesis success is essential.[4]

The use of small-diameter dental implants (3.5mm diameter) has become more popular in specific clinical situations such as a thin alveolar crest, replacing a tooth with small dimensions, or limited inter-radicular space. In addition to small-diameter implants, bone grafting procedure is an accepted treatment for placing wider implants in insufficient width of alveolar bone. However, some patients still refuse this kind of treatment because of the additional surgical (including tissue harvesting and bone grafting), cost and pain. Especially for autogenous bone grafting, many complications including par aesthesia and morbidity of the donor site have been reported.[5] Nevertheless, the use of small-diameter implants has to be considered along with their potential limitations. From a biomechanical aspect, small-diameter implants are structurally weaker than standard-size implants (4.3 mm diameter). An implant with a smaller diameter also has reduced surface area to accommodate bone to implant contact, which influences bone stress/strain transference and these high stress/strains may jeopardize the support provided by the bone surrounding the implant. Additionally, implants with smaller diameters have a high risk of fatigue failure. Nevertheless, some studies still report good results for small-diameter implants. Where alveolar bone width is limited, the use of narrow-diameter implants may produce good survival rates.

Many research studies have been done in implantology related to implant design, surgical protocol, immediate implant placement and loading protocols. The conventional two-piece implant design, features implant–abutment connection rendering the design with a weak link in the entire junction of implant body and abutment. To overcome this disadvantage of two- piece implants, one-piece dental implants were introduced.[6]

The design of an implant and bio-mechanical evaluation of dental implant and surrounding bone plays a key role in the success of a final restoration. So one-piece and two-piece dental implants with different diameters, was chosen for this study.

Materials and methodology

The three-dimensional finite element analysis corresponding to the geometric model was meshed using Ansys Pre-processor (ANSYS version 12.0 software). The bone block representing the maxillary anterior region was designed with volumes of both cortical and cancellous bone.

Modelling of the implants

A three-dimensional finite element model of Noble Bio-care Implant System was generated using Catia, popular modelling software. Four different types of implant models of different diameters of commercially well-known implant systems are used. The features of these implant systems are as follows:

1. Sample A: One-piece implant of 3.5.mm diameter and length of 10 mm in Anterior Maxilla region.
2. Sample B: Two-piece implant of 3.5mm diameter and length of 10 mm in Anterior Maxilla region.
3. Sample C: One-piece implant of 4.3 mm diameter and length of 10 mm in Anterior Maxilla region
4. Sample D: Two-piece implant of 4.3 mm diameter and length of 10 mm in Anterior Maxilla region.

Length of Implant: 10 mm

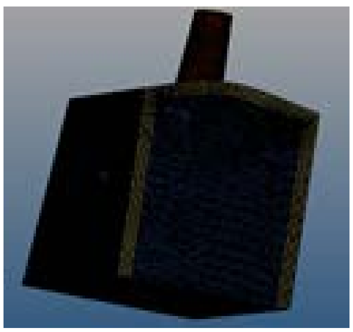

Fig. 1

The Density of Bone: Anterior Maxilla: D3 according to the Misch Classification.[7] (Porous cortical fine)

Samples of implants

Fig.2

Fig.3

Fig.4

Fig.5

Fig. 2: One-piece implant with 3.5 mm diameter

Fig. 3: Two-piece implant with 3.5 mm diameter

Fig. 4: One-piece implant with 4.3 mm diameter

Fig. 5: Two-piece implant with 4.3mm diameter

Specifying material properties: Three material properties were utilized i.e., young's modulus, Poisson's ratio and Tensile strength.

Table A

Material	Young's modulus	Poisson's ratio	Tensile Strength
Cortical bone	13700MPa	0.30	-
Cancellous bone	1370MPa	0.30	-
Implant (Titanium alloy)	110000MPa	0.35	-

Applying boundary conditions: Constraints were applied on the distal end of the model in all the three axes and omitting support at the bottom permitted bending of the model. These aspects make the model a more realistic representation of the clinical situation.

Table B

Model	No. of elements	No. of nodes
One piece implant with 3.5 mm diameter	606607	114156

One piece implant with 4.3 mm diameter	595757	112259
Two-piece implant with 3.5 mm diameter	626942	117951
Two-piece implant with 4.3 mm diameter	615577	115980

Application of forces on Models: Forces of 100N applied vertically and at 15degrees according to the long axis of the implant and the stress distribution pattern within the implant, crestal and peri-implant bone is studied and compared to each other.[8]

Results

A three-dimensional Finite Element Analysis was done to evaluate the stress distribution in implant body and surrounding structures (Cortical and Cancellous bone) in two different diameters of one-piece and two-piece dental implants with same length.

Table C: Von–Misses stress values: - Shows the values of Von-Misses stress at implant body and surrounding bone structures (Cancellous and Cortical)

	Overall Stress (Mpa)	Cortical Stress(Mpa)	Cancellous Stress(Mpa)	Implant Stress (Mpa)	Abutment Screw Section
Model 3.5(One-piece)	54.2	25.23	2.88	57.82	-
Model 3.5 (Two-piece)	87.34	32.87	3.88	87.34	49.44
Model 4.3 (One-piece)	42.904	15.41	1.63	36.33	-
Model 4.3 (Two-Piece)	58.77	22.71	1.96	58.77	27.56

From the observation following conclusions can be carried out

1. The overall stress is increased in Two-piece implants compared to the One-piece implants.
2. The overall deformation is not much dependent on either One-piece or Two-piece dental implants and very marginal change can be observed.

Diameter changes observations

1. The Cancellous stress is reduced with increase in the diameter of implant i.e. Von-Misses stress level are less in Cancellous bone with 4.3 mm diameter implants when compare to 3.5 mm diameter implants. Similarly cortical bone stress is also reduced with increase in the diameter of the implant.
2. Even the abutment screw connection stress is also reduced with increase in the diameter of implant. This can be attributed to larger resisting area with the increase in diameter of the implant.

A comparison of Von-Misses stress values of two-piece (3.5 mm and 4.3 mm diameter) dental implants and one-piece dental implants (3.5 mm and 4.3 mm diameters) at the implant body, Cancellous and cortical bone regions.

An analysis between different diameter implants (y-axis) and stress values (x-axis) for both One-piece and Two-piece implants (a statistical analysis).

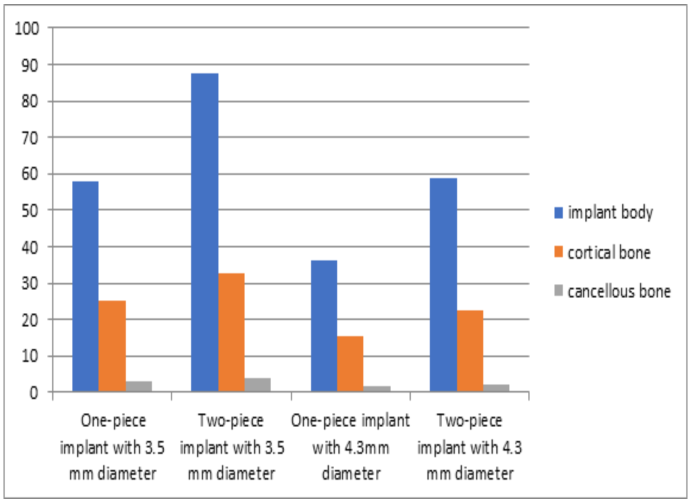

Fig.6: This analysis revels, Von-Misses stress in implant body, cortical and cancellous bone, decreased by increasing the implant diameters

Discussion

Dental implant is a prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal and/or periosteal layer and on/within the bone to provide retention and support for a fixed or removable dental prosthesis.[9]

The design of an implant plays a key role in the success o f a final restoration. The conventional two-piece implant design, features implant–abutment connection rendering the design with a weak link in the entire junction of implant body and abutment. To overcome this disadvantage of two-piece implants, one-piece dental implants were introduced. There are additional advantages of one-piece implants, such as it mimics natural tooth, strong unibody design and no split parts. The use of one-piece dental implants reduces the requirement of multiple surgical techniques and prosthetic components, thereby reducing the inventory and cost. One-piece dental implant can be placed by following the single stage surgical technique and this technique can be followed using either flap or flapless approach, and in limited interdental space, mandibular anteriors, maxillary laterals and first bicuspids.[10] This has shown good clinical success compared to that of two-piece implants because of its unibody structures. Micro-gap or micro-leakage is a common complication in two-piece implants because of the implant design, that is, separate parts of implant body and abutment. This can lead to local inflammation of soft tissue around the implant.[11,12] One-piece implants have no micro-gap between the implant and the abutment, and as a result the loss of alveolar bone around the implant is minimized. Various factors affect the success or failure of implants such as biomaterials used, biological considerations and biomechanical aspects. Biomechanical influences play an important role in maintaining bone morphology and physiology. Masticatory loads are transferred to the bone in the form of stresses; hence, the manner in which bone is loaded becomes a decisive factor in determining the response of the bone to implants. Stresses within physiological limits show adaptive response while the stresses exceeding the limit bring about restorative changes. The stress distribution in and around the implant depends upon implant geometry, magnitude and direction of forces, arrangement of implants when multiple implants are planned and relative elastic properties of the implant material and bone.

Implant diameter variations will play major role in stress distribution surrounding bone. The dimension measured from the peak of the widest thread to the same point on the opposite side of the implant. From a biomechanical standpoint, the use of wider implants allows engagement of a maximal amount of bone, and a theoretically improved distribution of stress in the surrounding bone. The use of wider components also allows for the application of higher torque in the placement of prosthetic components. The use of wide implants, however, is limited by the width of the residual ridge and aesthetic requirements for a natural emergence profile The known advantages of using wide-diameter implants include providing more bone-to-implant contact, bicortical engagement, immediate placement in failure sites, and a reduction in abutment stresses and strain.[13] A wide-diameter implant can also be used as an alternative to bone grafting in severely resorbed maxillae.[5] Histological sections of wide-diameter implants in bone show more total surface contact with bone than standard implants in standard photomicrographs made with a sonic digitizer.[14]

Applications of narrow-diameter implants were introduced for residual ridges that were too narrow for regular implants and for edentulous spaces with limited interdental width. The prime indication for narrow-diameter implants is in the replacement of mandibular incisors and maxillary lateral incisors. Narrow-diameter implants are also indicated when the proposed implant site is less than 5 mm in diameter. One of the primary disadvantages of narrow-diameter implants is the reduction in resistance to occlusal loading.[15]

Preservation of peri-implant marginal bone height thus depends, in part, on proper distribution of marginal stress; however, major variations in the abilities of different implant designs to resist and distribute vertical and lateral occlusal loads have been documented using three-dimensional (3D) Finite Element Stress Analysis (FEA).[16] The ability of one-piece dental implant designs to maintain peri-implant crestal bone levels to the same degree as two-piece implant designs has recently been questioned. The aim of this biomechanical analysis was to compare the level of stresses generated by one-piece and two-piece implant designs in simulated homogenous bone to determine if load distributions were significantly different. A limited number of FEA studies have been used to build the 3D FEA model database of the Maxilla. In these studies, the section of interest has been modelled 3-D FEA was used in the present study to compare the different diameters of one-piece and two-piece dental implants with same length.

The three-dimensional finite element models constructed for this study was a multi-layered complex 3structure involving 3.5mm and 4.3 mm diameter of one piece and two-piece dental implants with 10 mm length. On the basis of data obtained from this study as well as previous studies, following clinical recommendations about the use of one-piece dental implant with 4.3 mm diameter and 3.5 mm diameter are given:

1. Von-Mises stress in implant body, cortical and cancellous bone, decreased by increasing the implant diameters. The overall deformation is not much dependent on either one-piece or two-piece implants. Very marginal changes observed.

Within the limitations of FEA study few clinical inferences can be:

- Highest Von–Mises stresses are observed in two-pieces 3.5 mm diameter implant and least Von-misses stress are observed in one-piece 4.3 mm diameter implants.
- The stress which is related to implants and surrounding structures are subjected is difficult to estimate.
- Dental history, particularly a history of parafunctional activity, bone deficiency, most esthetical consideration at implant placement region is indicated.

Conclusion

One-piece implants have become increasingly popular in the last few years. The strong unibody design, no split parts, single stage surgery and absence of a micro gap between the implant and the abutment at bone crest level offers one piece implants many clinical and technical advantages.

Thus, it can be concluded that

One-piece dental implant with 3.5 mm diameter shows better success rate, and less von- Mises stress levels in implant and surrounding bone (cortical and cancellous bone) when compare to two-piece dental implant with 3.5 mm diameter. One-piece dental implant with 4.3 mm diameter shows better success rate, and less von-Mises stress levels in implant and surrounding bone (cortical and cancellous bone) when compare to two-piece dental implant with 4.3 mm diameter. One-piece dental implant with 4.3 mm diameter shows better success rate, and less Von-Mises stress levels in implant and surrounding bone (cortical and cancellous bone) when compare to one - piece dental implant with 3.5 mm diameter.

References

1. Akca K and Iplikcioglu H. Finite element stress analysis of the influence of staggered versus straight placement of dental implants. Int J Oral Maxillfac Implants 2001; 16:722-730.
2. Branemark PI, Zarb GA, Albrektsson T. Tissue integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago, IL: Quintessence; 1985.
3. Kheur MG, Parulekar N, Jambhekar SS. Clinical Considerations for Cementation of Implant Retained Crowns. Ind J Dent Advancements 2010; 2(2):180-181.
4. Hsu ML and Chang CL. Finite Element Analysis. Intech Pub; 2010.
5. Mahon JM, Norling BK, Phoenix RD. Effect of varying fixture width on stress and strain distribution associated with an implant stack system. Implant Dent 2000; 9:310-20.
6. Adell R, Lekholm U, Rockler B, et al. A 15-year study of osseointegrated implants in the treatment of edentulous jaw. Int J Oral Surg. 1981; 10: 387-416.
7. Dutmanee Seriwatanachai, Sirichai Kiattavorncharoen et al: Reference and Techniques used in Alveolar Bone Classification. J Interdiscipl Med Dent sci, vol- 3, (2015)
8. Stuart J McNally, Chuck Wilcox1, Mohammed P Akhter2, James L Sheets1, John R Danforth2, Hardeep K Chehal; Implant diameter: Effect on stress in bone: Finite element analysis; Journal of Dental Implants, Jul - Dec 2013, Vol 3, Issue 2; DOI: 10.4103/0974-6781.118854
9. Glossary of Prosthodontic terms, 9th Edition. J Prosthet Dent 2017; 117(5).
10. Fortin T, Bosson JL, Isidori M, et al: Effect of flapless surgery on pain experienced in implant placement using an image-guided System. Int J Oral Maxillofac Implants 2006; 21:298-304.
11. N. Broggini, L.M. McManus, J. S. Hermann et al. Peri-implant inflammation defined by the implant-abutment interface. Journal of Dental Research, vol. 85, no. 5, pp. 473–478, 2006.
12. Hermann JS, Buser D, Schenk RK, et al: Biological width around one piece and two-piece implants. Clin Oral Implants Res 2001; 12:559-571.
13. Langer B, Langer L, Herrmann I, Jorneus L. The wide fixture: a solution for special bone situations and a rescue for the compromised implant. Part 1. Int J Oral Maxillofac Implants 1993; 8:400-8.
14. Hallman M. A prospective study of treatment of severely resorbed maxillae with narrow non submerged implants: results after 1 year of loading. Int J Oral Maxillofac Implants 2001; 16:731-6.
15. Ettinger RL, Spivey JD, Han DH, Koorbusch GF. Measurement of the interface between bone and immediate end osseous implants: a pilot study in dogs. Int J Oral Maxillofac Implants 1993; 8:420-7.

16. Himmlova L, Dostal ova T, Kacovsky A, Konvickova S. Influence of implant length and diameter on stress distribution: a finite element analysis. J Prosthet Dent 2004; 91:20-5.