International Journal of Research in Health and Allied Sciences

Journal home page: www.ijrhas.com

Official Publication of "Society for Scientific Research and Studies" [Regd.]

ISSN: 2455-7803

Original Research

Three-dimensional finite element analysis of effect of abutment materials on stress distribution around peri-implant bone in immediate and delayed loading conditions

[1]Dr. Sumit Bhatt, [2]Dr. Saurabh S Simre, [3]Dr. Vijay Parmar, [4]Dr. Anjali Rathore, [5]Dr. Priyanka Shah, [6]Dr. Pratik Bumb

[1]Senior Lecturer, Department of Oral and Maxillofacial Surgery, Rajasthan Dental College and Hospital, Jaipur Rajasthan, India;
[2]Senior Resident, Department of Dentistry, AIIMS Rishikesh, Uttarakhand, India;
[3]Senior Lecturer, Department of Prosthodontics, Goenka Research Institute of Dental Science, Gandhinagar, Gujarat, India;
[4]Senior Resident, Department of Dental Surgery, Raipur Institute of Medical Science, Raipur, Chhattisgarh, India;
[5]Reader, Department of Periodontology, Vasant Dada Patil Dental College and Hospital, Kavlapur, (MUHS University) Sangli, Maharashtra, India;
[6]Senior Lecturer, Department of Prosthodontics and Crown and Bridge, Teerthankar Mahaveer Dental College and Research Centre, Moradabad, U.P, India

ABSTRACT:
Background: Oral rehabilitation entered a new era with the creation of osseointegrated dental implants. The excellent success rate and long-term follow-up (more than 20 years) of patients treated with osseointegrated dental implants are of interest to clinicians and researchers worldwide. The present study was conducted to assess three-dimensional finite element analysis of effect of abutment materials on stress distribution around peri-implant bone in immediate and delayed loading conditions. **Materials & Methods:** Six abutment groups were loaded from vertical, horizontal, and oblique directions. Group I had zirconia with delayed loading (DL), group II had Polyether Ether Ketone (PEEK) with DL, group III had Titanium grade extra low interstitial (ELI) with DL, group IV had zirconia with immediate loading (IL), group V had PEEK with IL, and group VI had titanium grade ELI with IL. Using the finite element approach, von Mises and main stress analysis was performed on the implant and the peri-implant bone. **Results:** Group II, or PEEK customized abutment with titanium implant, had the highest maximum and lowest stress values in the cortical bone. Group III, or titanium grade ELI abutment, came in second, and group I, or zirconia customized abutment assembly, had the lowest value. Group I had the highest maximum and lowest stress values in the cancellous bone, followed by group III, while group II had the lowest value. Group V—the PEEK customized abutment with titanium implant—acquired the highest maximum and lowest stress values in the cortical bone. However, group IV had the highest maximum and lowest stress values in the cancellous bone, followed by group VI, and group V had the lowest value. **Conclusion:** The stress produced in the implant and the peri-implant tissue is impacted by changes in the abutment material. In both immediate and delayed loading conditions, PEEK abutments demonstrated noticeably less von Mises stress in the implant body than titanium and zirconia.
Keywords: abutments, cancellous bone, peri-implant

Received Date: 18 October, 2024 Acceptance Date: 23 November, 2024

Corresponding author: Dr. Sumit Bhatt, Senior Lecturer, Department of Oral and Maxillofacial Surgery, Rajasthan Dental College and Hospital, Jaipur Rajasthan, India

This article may be cited as: Bhatt S, Simre SS, Parmar V, Rathore A, Shah P, Bumb P. Three-dimensional finite element analysis of effect of abutment materials on stress distribution around peri-implant bone in immediate and delayed loading conditions. Int J Res Health Allied Sci 2024; 10(6):21-24.

INTRODUCTION

Oral rehabilitation entered a new era with the creation of osseointegrated dental implants. The excellent success rate and long-term follow-up (more than 20 years) of patients treated with osseointegrated dental implants are of interest to clinicians and researchers worldwide. For dental implant procedures to be successful, osseointegration must exist.[1] The Branemark protocol consists of two steps. In the initial phase, the implant is placed and immersed beneath a hermetically sutured mucosa to permit normal healing without the possibility of bacteremia in the absence of any functional stimulation.[2] After the implant has been exposed, an abutment is attached, and if osseointegration has occurred, a restoration is placed on the abutment. To circumvent the major psychological, cosmetic, and functional impairments linked to the four to six months recovery period, a one-step surgical technique was created. This method uses non-submerged implants, and loading typically starts earlier than with Brandemark procedures.[3]

This strategy is called "immediate loading" In order to lower the danger of early failure or marginal bone loss, progressive loading is the technique of progressively loading an implant from one transition state to the next.[4] Progressive or gradual bone loading is essential at the beginning of prosthodontic therapies, particularly for less dense bone types. Wolff's law states that trabecular bone positions and displaces itself in predictable patterns, and the implant's progressive loading enables the bone to remodel and arrange in accordance with this law.[5] More and more helpful tools for creating new materials to improve clinical outcomes in the biomedical sciences have been made available by digitalization. Finite Element Analysis (FEA) is an engineering method to solve complicated mechanical problems by simulation of force upon a constructed or a scanned model.[6] The present study was conducted to assess three-dimensional finite element analysis of effect of abutment materials on stress distribution around peri-implant bone in immediate and delayed loading conditions.

MATERIALS & METHODS

The study was carried out on a titanium grade IV root form implant, fitted with an abutment Ø4.0-0.5GH. This test model was scanned in three dimensions (3D) and recreated using CREO computer-aided design software. Six abutment groups were loaded from vertical, horizontal, and oblique directions. Group I had zirconia with delayed loading (DL), group II had Polyether Ether Ketone (PEEK) with DL, group III had Titanium grade extra low interstitial (ELI) with DL, group IV had zirconia with immediate loading (IL), group V had PEEK with IL, and group VI had titanium grade ELI with IL. Using the finite element approach, von Mises and main stress analysis was performed on the implant and the peri-implant bone. Results thus obtained were subjected to statistical analysis. P value < 0.05 was considered significant.

RESULTS

Table I Maximum and Minimum Principal stress values in cortical and cancellous bone in delayed loading condition

Groups	Load direction	Stress cortical S		Stress cancellous	
		Maximum	Minimum	Maximum	Minimum
Group I	Vertically loading	34.6	4.2	44.7	16.1
	Obliquely at 30˚				
	Horizontally loading				
Group II	Vertically loading	151.7	25.3	11.8	2.5
	Obliquely at 30˚				
	Horizontally loading				
Group III	Vertically loading	38.4	8.4	38.3	7.1
	Obliquely at 30˚				
	Horizontally loading				

Table I shows that group II, or PEEK customized abutment with titanium implant, had the highest maximum and lowest stress values in the cortical bone. Group III, or titanium grade ELI abutment, came in second, and group I, or zirconia customized abutment assembly, had the lowest value. Group I had the highest maximum and lowest stress values in the cancellous bone, followed by group III, while group II had the lowest value.

Table II Maximum and Minimum Principal stress values in cortical and cancellous bone in immediate loading condition

Groups	Load direction	Stress cortical		Stress cancellous	
		Maximum	Minimum	Maximum	Minimum
Group IV	Vertically loading	51.1	7.8	65.2	23.8
	Obliquely at 30˚				
	Horizontally loading				
Group V	Vertically loading	230.5	40.6	16.4	4.2
	Obliquely at 30˚				
	Horizontally loading				

Group VI	Vertically loading	58.4	12.3	58.9	11.7
	Obliquely at 30˚				
	Horizontally loading				

Table II shows that group V—the PEEK customized abutment with titanium implant—acquired the highest maximum and lowest stress values in the cortical bone. However, group IV had the highest maximum and lowest stress values in the cancelous bone, followed by group VI, and group V had the lowest value.

DISCUSSION

To identify the best abutment material for long-term implant life, several authors have assessed how various abutment materials affect load transmission to the implant and surrounding bone.[7] The bone implant interface must be a crucial factor in these simulations, however the majority of FEA models assume ideal osseointegration, which isn't always the case in clinical settings.[8] Since the world is drastically moving toward immediate loading protocols, it is also necessary to assess the poor attachment between the implant surface and the surrounding bone.[9,10] The present study was conducted to assess three-dimensional finite element analysis of effect of abutment materials on stress distribution around peri-implant bone in immediate and delayed loading conditions.

We found that group II, or PEEK customized abutment with titanium implant, had the highest maximum and lowest stress values in the cortical bone. Group III, or titanium grade ELI abutment, came in second, and group I, or zirconia customized abutment assembly, had the lowest value. Group I had the highest maximum and lowest stress values in the cancellous bone, followed by group III, while group II had the lowest value. Aggarwal et al[11] in their study found that for delayed loading group, highest stresses were generated in group 1 (462.88 MPa), followed by group 3 (413.72 MPa) and least in group 2 (319.38 MPa). For immediate loading, highest to lowest stresses were in group 4 (694.32 MPa), group 6 (620.58 MPa) and group 5 (479.07 MPa). The principal stress analysis showed significant difference between all groups in cancellous bone and cortical bone except between titanium and customised zirconia abutment in cortical bone in delayed loading (p=0.0846) and in immediate loading (p=0.1125).

We found that group V—the PEEK customized abutment with titanium implant—acquired the highest maximum and lowest stress values in the cortical bone. However, group IV had the highest maximum and lowest stress values in the cancellous bone, followed by group VI, and group V had the lowest value. El-Anwar MI et al[12] evaluated the stress distribution in the bone surrounding implant. Threaded titanium dental implants were examined using three different abutment materials: zirconium, alumina, and titanium. Loading was applied vertically as compressive loading on five selected nodes on top of a metal crown coated with porcelain. Von Mises stress and equivalent deflection values in the cortical and cancellous bone were calculated, as well as in the crown, abutment, and implant. The results of the analysis showed that the abutment material did not affect stress distributions on spongy and cortical bones. However, it affected crown and implant stresses and deformation values

CONCLUSION

Authors found that the stress produced in the implant and the peri-implant tissue is impacted by changes in the abutment material. In both immediate and delayed loading conditions, PEEK abutments demonstrated noticeably less von Mises stress in the implant body than titanium and zirconia.

REFERENCES

1. Chun HJ, Shin HS, Han CH, Lee SH. Influence of implant abutment type on stress distribution in bone under various loading conditions using finite element analysis. Int J Oral Maxillofac Implants. 2006;21(2):195-202.
2. Sevimay M, Turhan F, Kiliçarslan MA, Eskitascioglu G. Three-dimensional finite element analysis of the effect of different bone quality on stress distribution in an implant-supported crown. J Prosthet Dent. 2005;93(3):227-34.
3. Sannino G, Gloria F, Ottria L, Barlattani A. Influence of finish line in the distribution of stress trough an all ceramic implant-supported crown: A 3D finite element analysis. Oral Implantol. 2009;2(2):14.
4. Mourya A, Nahar R, Mishra SK, Chowdhary R. Stress distribution around different abutments on titanium and CFR-PEEK implant with different prosthetic crowns under parafunctional loading: A 3D FEA study. J Oral Biol Craniofac Res. 2021;11(2):313-20.
5. Gao J, Matsushita Y, Esaki D, Matsuzaki T, Koyano K. Comparative stress analysis of delayed and immediate loading of a single implant in an edentulous maxilla model. J Dent Biomech. 2014;5:1758736014533982.
6. Kitamura E, Stegaroiu R, Nomura S, Miyakawa O. Influence of marginal bone resorption on stress around an implant– A three-dimensional finite element analysis. J Oral Rehabil. 2005;32(4):279-86.
7. Sahin S, Cehreli MC, Yalçın E. The influence of functional forces on the biomechanics of implant-supported prostheses-A review. J Dent. 2002;30(7-8):271-82
8. Shash M, Nazha H, Abbas W. Influence of different abutment designs on the biomechanical behavior of one-piece zirconia dental implants and their surrounding bone: A 3D-FEA. Irbm. 2019;40(6):313-39.
9. Li ZY, Niu W, Fang W, Hu J, Wang YN. Clinical evaluation of ceramic and titanium abutment for implant-supported all-ceramic single crown. Zhonghua Kou Qiang Yi Xue Za Zhi. 2007;42(7):391-94.
10. Tretto PH, Dos Santos MB, Spazzin AO, Pereira GK, Bacchi A. Assessment of stress/strain in dental implants and abutments of alternative materials

compared to conventional titanium alloy—3D non-linear finite element analysis. Comput Methods Biomech Biomed Engin. 2020;23(8):372-83.

11. Agarwal S, Trivedi A, Kusum CK, Goswami R, Mowar A. A Three-dimensional Finite Element Analysis of Effect of Abutment Materials on Stress Distribution around Peri-Implant Bone in Immediate and Delayed Loading Conditions. Journal of Clinical & Diagnostic Research. 2022 Jun 1;16(6).
12. El-Anwar MI, Fawzy UM, Mohamad HA, Tamam RA, Yousief SA. Effect of different abutment materials of implant on stress distribution using three-dimensional finite element analysis. Medical Research Journal. 2013;12(2):115-23.
13. Kumar K, Shetty DC, Wadhwan V, Dhanapal R, Singh HP. Dentinoameloblastoma with ghost cells: A rare case report with emphasis on its biological behavior. Dent Res J 2013;10:103-7.
14. Singh HP, Kumar P, Goel R, Kumar A. Sex hormones in head and neck cancer: Current knowledge and perspectives. Clin Cancer Investig J 2012;1:2-5.
15. Singh HP, Kumar P, Goel R, Kumar A. Sex hormones in head and neck cancer: Current knowledge and perspectives. Clin Cancer Investig J 2012;1:2-5.
16. Singh HP, Shetty DC, Kumar A, Chavan R, Shori DD, Mali J. A molecular insight into the role of inflammation in the behavior and pathogenesis of odontogenic cysts. Ann Med Health Sci Res 2013;3:523-8.