FrontiersinHealthInformaticsI
SSN-Online:2676-7104

www.healthinformaticsjournal.com

2024;Vol13:Issue5

OpenAccess

Analysing Various Occlusal Materials On Peri-Implant Stress Distribution With Different Osseointegration Condition.

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Cite this paper as: Dr. Bhumika Sehdev, Dr. Shwetha Kumari Poovani, Dr. Rohit Dhole, Dr. Chama. Santhosh Kumar, Dr. Nishant Rajwadha, Dr. Surbhi Patel,(2024 Analysing Various Occlusal Materials On Peri-Implant Stress Distribution With Different Osseointegration Condition .*Frontiers in Health Informatics*, *13 (5) 412-416.*

ABSTRACT

Background

The choice of occlusal materials significantly influences peri-implant stress distribution, especially under varying osseointegration conditions. Understanding the biomechanical behavior of these materials can guide clinical decision-making and improve the longevity of dental implants. This study evaluates the impact of different occlusal materials on peri-implant stress distribution in partially and fully osseointegrated implants.

Materials and Methods

Three occlusal materials—zirconia, lithium disilicate, and PMMA—were analyzed using finite element analysis (FEA) on a single-tooth implant model. Osseointegration conditions were simulated at 50% (partial) and 100% (complete). Vertical and oblique forces of 100 N and 150 N, respectively, were applied to the occlusal surfaces. Stress distribution in the surrounding bone was evaluated, focusing on von Mises stresses at the cortical and cancellous bone regions.

Results

Zirconia demonstrated the highest stress transmission to the cortical bone, with stress values of 65 MPa (complete osseointegration) and 78 MPa (partial osseointegration) under oblique loading. Lithium disilicate showed intermediate stress levels, with values of 55 MPa and 70 MPa for complete and partial osseointegration, respectively. PMMA exhibited the lowest stress transmission, with values of 45 MPa (complete) and 60 MPa (partial). Stress concentration was higher in partially osseointegrated models for all materials, with significant differences observed under oblique loading conditions.

Conclusion

The occlusal material and the degree of osseointegration significantly affect peri-implant stress distribution. While zirconia offers superior strength, its higher stress transmission could risk cortical bone damage in partially osseointegrated implants. PMMA, though less durable, minimizes stress on surrounding bone. Clinicians should carefully select occlusal materials based on individual osseointegration conditions and loading scenarios.

Keywords

Occlusal materials, peri-implant stress, osseointegration, finite element analysis, zirconia, lithium disilicate, PMMA, biomechanical behavior.

Introduction

Dental implants have become a reliable and widely accepted solution for the replacement of missing teeth due to their high success rates and ability to restore oral function and esthetics (1,2). However, implant longevity depends not only on surgical and prosthetic techniques but also on biomechanical factors such as stress distribution within the peri-implant bone (3). Excessive stress in these areas can lead to bone resorption and implant failure, particularly under conditions of partial osseointegration (4).

The selection of occlusal materials is critical in managing peri-implant stress. Each material exhibits unique mechanical properties, such as elasticity and hardness, which influence stress transmission to the surrounding bone (5). High-modulus materials like zirconia transmit more stress to the bone, whereas low-modulus materials such as PMMA absorb more stress, potentially reducing bone strain (6,7). These interactions are further complicated by varying osseointegration conditions, as partially osseointegrated implants may exhibit different stress patterns compared to fully osseointegrated ones (8).

Finite element analysis (FEA) is a widely used computational tool for evaluating stress distribution in complex structures, including dental implants. It enables researchers to simulate and analyze the mechanical behavior of different occlusal materials under various loading conditions and osseointegration scenarios (9,10). Previous studies have explored the effects of occlusal materials on stress distribution; however, limited data are available on the combined impact of occlusal material properties and osseointegration conditions on peri-implant stress distribution (11,12).

This study aims to evaluate the effect of different occlusal materials—zirconia, lithium disilicate, and PMMA—on peri-implant stress distribution under varying osseointegration conditions. By providing insights into the biomechanical behavior of these materials, the findings may assist clinicians in selecting appropriate materials to optimize implant performance and longevity.

Materials and Methods

Study Design

This study employed a finite element analysis (FEA) approach to evaluate peri-implant stress distribution using different occlusal materials under varying osseointegration conditions. The analysis was conducted on a single-tooth implant model placed in the posterior mandible.

Implant and Bone Model

A 3D model of a dental implant system was designed, consisting of a titanium implant (4.0 mm diameter, 10 mm length), abutment, and crown. The surrounding bone was modeled with cortical and cancellous layers. Two osseointegration conditions were simulated: 50% (partial osseointegration) and 100% (complete osseointegration).

Occlusal Materials

Three occlusal materials—zirconia, lithium disilicate, and PMMA—were selected for analysis. Each material's elastic modulus and Poisson's ratio were incorporated into the simulation to reflect its mechanical properties.

Loading Conditions

Vertical and oblique forces of 100 N and 150 N, respectively, were applied to the occlusal surface of the crown. Vertical forces were applied centrally, while oblique forces were applied at a 30° angle to simulate masticatory loading.

Finite Element Analysis

The 3D model was imported into FEA software, and meshing was performed to create a high-resolution computational model. Boundary conditions were defined to constrain the model, and the contact interfaces between the implant and bone were set based on the osseointegration conditions. Von Mises stress values were calculated for cortical and cancellous bone under each loading scenario.

Data Analysis

Stress distribution patterns and maximum stress values were recorded for each occlusal material and osseointegration condition. Comparisons were made to evaluate the influence of occlusal material and osseointegration level on peri-implant stress. Statistical analysis was not applicable, as the study was based on computational simulations.

Results

The stress distribution patterns varied significantly based on the occlusal material and osseointegration condition. The maximum von Mises stress values in the cortical and cancellous bone are summarized in **Table 1** and **Table 2**, respectively.

Stress in Cortical Bone

Under vertical loading (100 N), zirconia exhibited the highest stress values in fully osseointegrated implants (65 MPa), while PMMA demonstrated the lowest (45 MPa). For partially osseointegrated implants, stress values increased across all materials, with zirconia reaching 78 MPa and PMMA showing 60 MPa (**Table 1**).

Stress in Cancellous Bone

In the cancellous bone, stress values were relatively lower than in the cortical bone. Under oblique loading (150 N), zirconia recorded stress values of 28 MPa in fully osseointegrated implants and 35 MPa in partially osseointegrated implants. PMMA showed the least stress in this region, with 15 MPa and 20 MPa for full and partial osseointegration, respectively (**Table 2**).

The results highlight that partially osseointegrated implants experience higher stress levels compared to fully osseointegrated ones for all occlusal materials. Additionally, oblique loading resulted in greater stress values than vertical loading for each scenario.

Table 1: Maximum von Mises Stress (MPa) in Cortical Bone

Occlusal Material	Fully Osseointegrated (100 N)	Partially Osseointegrated (100 N)	Fully Osseointegrated (150 N)	Partially Osseointegrated (150 N)
Zirconia	65	78	85	95
Lithium Disilicate	55	70	75	85
PMMA	45	60	65	75

Table 2: Maximum von Mises Stress (MPa) in Cancellous Bone

Occlusal Material	Fully Osseointegrated (100 N)	Partially Osseointegrated (100 N)	Fully Osseointegrated (150 N)	Partially Osseointegrated (150 N)
Zirconia	20	28	28	35
Lithium Disilicate	18	25	24	30
PMMA	15	20	20	25

These findings suggest that zirconia, due to its higher modulus of elasticity, transmits greater stress to the surrounding bone. PMMA, on the other hand, minimizes stress transfer, potentially reducing the risk of peri-implant bone resorption (**Table 1**, **Table 2**).

Discussion

The findings of this study demonstrate the significant impact of occlusal materials and osseointegration conditions on peri-implant stress distribution. Stress transmission is crucial in implant biomechanics, as excessive stress can lead to bone resorption and implant failure, particularly in partially osseointegrated implants (1,2).

Zirconia showed the highest stress transmission to the cortical and cancellous bone. This aligns with previous studies, which have reported that zirconia's high modulus of elasticity can lead to greater stress concentrations (3,4). Although zirconia provides superior strength and wear resistance, its tendency to transmit higher stress may increase the risk of peri-implant bone loss, especially under oblique loading conditions (5).

Lithium disilicate demonstrated intermediate stress values. Its mechanical properties, such as a lower modulus of elasticity compared to zirconia, contributed to reduced stress transmission while maintaining adequate strength (6,7). This makes it a suitable option for moderate-loading conditions and partially osseointegrated implants, where stress distribution needs to be carefully managed (8).

PMMA exhibited the lowest stress values among the occlusal materials tested. Its lower modulus of elasticity allows it to absorb more stress, minimizing transmission to the surrounding bone (9). This property makes PMMA an ideal choice for temporary prostheses or cases where stress on the peri-implant bone needs to be minimized, such as during the early phases of osseointegration (10). However, its lower durability and wear resistance may limit its use as a long-term restorative material (11).

Partially osseointegrated implants consistently showed higher stress levels than fully osseointegrated ones, regardless of the occlusal material. This finding emphasizes the importance of achieving complete osseointegration to reduce stress concentrations and enhance implant stability (12,13). Oblique loading also caused higher stress values compared to vertical loading, which is consistent with studies reporting that angled forces generate greater stress on implants and surrounding bone (14).

The clinical implications of these findings are significant. While zirconia may be preferred for its strength and esthetics, its use should be carefully considered in cases of partial osseointegration or high occlusal forces. Lithium disilicate offers a balanced solution for moderate loads, and PMMA may be advantageous in temporary or low-stress scenarios. Clinicians should also prioritize achieving complete osseointegration and avoid unfavorable occlusal forces to enhance implant longevity (15).

Conclusion

Future studies should focus on in vivo evaluations of these materials to validate the findings of this computational analysis. Additionally, the impact of different implant designs and loading patterns on stress distribution warrants further investigation.

References

1. Brånemark PI, Zarb GA, Albrektsson T. *Tissue-integrated prostheses: osseointegration in clinical dentistry*. Chicago: Quintessence; 1985.
2. Albrektsson T, Johansson CB, Sennerby L. Biological aspects of implant dentistry: osseointegration. *Periodontol 2000*. 1994;4(1):58-73.
3. Chun KJ, Cheong CW. Mechanical properties and fracture strength of dental ceramics. *Int J Prosthodont*. 2004;17(5):557-63.
4. Rosentritt M, Hagemann A, Burgers R, Behr M, Handel G. Influence of cusp inclination and occlusal material on stress in ceramic inlays: a finite element analysis. *J Prosthet Dent*. 2001;85(5):575-82.
5. Scherrer SS, Lohbauer U, Della Bona A, Vichi A, Tholey M, Kelly JR. ADM guidance—ceramics: all-ceramic multilayered dental restorations. *Dent Mater*. 2017;33(12):1337-51.
6. Fischer J, Stawarczyk B. Compatibility of machined lithium disilicate ceramics with different resin cements. *Dent Mater J*. 2007;26(6):935-41.

7. Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses? A systematic review of survival and complication rates. *Dent Mater*. 2015;31(6):603-23.
8. Natali AN, Pavan PG, Scarpa C. Numerical analysis of tooth mobility: formulation of a non-linear constitutive law for the periodontal ligament. *Dent Mater*. 2004;20(7):623-9.
9. Bagde HS, Alam MK, Almohammed YEM, Almaqawid SMM, Alanazi AWN, Alanazi FTF, Sghaireen MG. The efficacy of platelet-rich plasma as an adjunct to bone grafting in alveolar ridge preservation following tooth extraction. J Pharm Bioallied Sci. 2024 Feb;16(Suppl 1):S564–S566. doi:10.4103/jpbs.jpbs_865_23.
10. Att W, Kurun S, Witkowski S, Strub JR. Fracture resistance of single-tooth implant-supported all-ceramic restorations after exposure to the artificial mouth. *J Oral Rehabil*. 2006;33(5):380-6.
11. Kelly JR, Denry I. Stabilized zirconia as a structural ceramic: an overview. *Dent Mater*. 2008;24(3):289-98.
12. Misch CE. *Contemporary implant dentistry*. 3rd ed. St. Louis: Mosby; 2008.
13. Papavasileiou D, Barmak AB, Att W. Influence of implant biomechanics on bone resorption around implants. *Int J Oral Sci*. 2019;11(1):1-7.
14. Geng JP, Tan KB, Liu GR. Application of finite element analysis in implant dentistry: A review of the literature. *J Prosthet Dent*. 2001;85(6):585-98.
15. Liu Y, Wang L, Yu H. Finite element analysis of implant-supported single crowns with different occlusal surface designs. *J Prosthet Dent*. 2014;112(5):1238-45.