Comparative Evaluation Of Stress Distribution On Splinted And Non-Splinted Implant Supported Prosthesis With Different Implant Dimension In Posterior Maxilla: A Finite Element Analysis Study

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ABSTRACT

Aim

The aim of this study is comparative evaluation of stresses on splinted and non splinted implant supported prosthesis with different dimension of implant in posterior maxilla using finite element analysis method

Materials and Method:

The current study involved the meticulous construction of dental implants, abutments, and prosthesis, as well as the application of forces to mimic the clinical conditions with help of finite element analysis.

Results

The study found that short and wide implants exhibited higher von Mises strains in all components compared to long, thin implants, particularly under oblique loading. Vertical loading significantly reduced stress across all components. Oblique loading concentrated maximum principal stress on the bone surrounding the implant neck. Splinted crowns demonstrated lower stress levels than separate crowns under both vertical and oblique loads, indicating improved stress distribution. These findings suggest that implant dimensions and restoration design significantly influence stress distribution and bone interaction, with oblique loading posing a critical challenge.

Conclusion : Within the limitations of the study, optimized implant designs exhibit peak strain at the implant-abutment interface, highlighting this area as a critical stress concentration point. Splinted implant restorations demonstrate a reduced rate of stress distribution compared to non-splinted restorations, suggesting improved load sharing and potentially enhanced longevity. Furthermore, angled loading significantly increases moment forces on implants compared to vertical loading, underscoring the importance of considering loading direction in implant design and restoration.

Introduction

Dental implants of standard and short length are popular options for restoring esthetic and functional problems caused by tooth loss.[1] Maintenance of bone tissue around the implant, however, is still considered to be a significant challenge, primarily for implants placed in atrophic maxillary posterior region. Generally, the available bone tissue present in this area is insufficient for the placement of longer implants. In these cases, supplementary surgical procedures, such as maxillary sinus augmentation, have been suggested for placement of dental implant. However, this surgery is associated with a higher risk for surgical complications, morbidity, and a higher cost of treatment. Therefore, short implants are considered to be a simple and effective rehabilitation alternative in cases of limited bone quantity in the maxillary posterior region.[2,3] During functional movements, stresses on the implant-supported prosthesis are transmitted to the surrounding tissues through the implants. The ultimate tensile and compressive strengths of the cortical bone have been reported to be approximately 100 to 121 MPa and 167 to 173 MPa, respectively.[4] Although information is available regarding ultimate compressive and tensile strength, stress values that cause in vivo biological changes (absorption and remodeling) in the bone are lacking. Therefore, the main goal in implant supported restorations should be to reduce stress values and provide even stress distribution.[1]

Studies reported that occlusal overload induces unwanted bone remodelling. The occlusal overload promotes a moment in the implant that entails on peri-implant bone permanent damage. [5] According to several studies included[6,7,8,9] success factors for dental implants include mean bone loss of 1.5 mm in the first functional year and <0.20 mm/year after that, as well as the formation of biologic width without clinical features of implant infection linked to surgical trauma, peri implantitis, occlusal overload, implant macroscopic characteristics at neck region in contact with bone, implant-abutment interface, and micro-gap position.[4] Different implant macrode signs such as short (>6 to <10 mm) and extrashort dental implants (<6mm) provide solutions for rehabilitating posterior regions with severe bone resorption.[10] In many clinical situations, it is impossible to place dental implants since there is not enough residual vertical bone height that is to say, not every patient has adequate bone volumes to receive dental implants. This condition is common especially below the maxillary sinuses. Due to a limited ridge height following the expansion of the sinus maxillaries and vertical bone loss of the ridge after tooth extraction in the posterior region of the maxilla, primary implant placement is often difficult to achieve. Bone augmentation is the most common method to solve this problem. Generally, there are two options existing to increase the ridge height in the posterior maxilla (1) a sinus floor elevation procedure inacranial direction, using a transalveolar or a lateral window approach; (2) vertical bone regeneration in a caudal direction.[12,13] The first option is worth to recommend in case of a severely reduced ridge height. However, there are three main problems associated with bone augmentation procedures in general: the cost and duration of the treatment, the higher patient morbidity, and not necessarily ideal success rates. The results of systematic reviews showed that the lateral window approach and simultaneous implant placement demonstrated complications to occur in up to 38% ofthe patients and implants to fail in up to 17% within 3 years.[8] Therefore, current clinical researchesare focusing on evaluating the performance of short implants (5–8 mm). In addition, costs, surgical time, and morbidity associated with the procedures also play a key role. Even so, there is a lack of high quality researches of comparing short implants and long implants placed in the posterior maxilla. [6]

Methodology

For this study, the model components of ADIN implant system were created according to the manufacturer's dimension (Ø3.75x11.5 and Ø 5x6.25), using "AutoCad Inventor 2017". The same was done to create model components of bone, abutment, screw and restorative crowns on maxillary premolar and molar. The model components were further assembled in "SOLIDWORKS 2017" to obtain a complete assembled model.

Finite element analysis uses a complex system of points (nodes) and elements, which make a grid called as mesh made using "Hypermesh 2017" which have 3° of freedom. This mesh was programmed to contain the material and structural properties such as elastic modulus and Poisson's ratio, which defined how the structure reacted to certain loading conditions. Stress analysis was done using structural stress analysis software ANSYS 19.2 and carried out by applying load. ANSYS 19.2 generated simultaneous equation for each finite element through meshing and this solved to yield predictable stress distribution inimplant components and around peri-implant bone. Data was collected, collated and then subjected to analysis.

A total of 4 CAD models were created using 3-Dimensional Software. In each model, Internal Hex Connection implant were created using CAD Software according to manufacturer's dimensions and were placed in the missing molar and premolar region.

Model I - Implant system modelled to short and and standard implant with splinting undervertical load.

Model II - Implant system modelled to short and standard implant with non splinting undervertical load.

Model III - Implant system modelled to short and standard implant with splinting under obliqueload.

Model IV - Implant system modelled to short and standard implant with non splinting underoblique load.

The complete study was divided into 4 steps

Step 1 – Construction of CAD Models.

Step 2 – Generation of Finite Element Models.

Step 3 – Assigning material properties and application of loading conditions.

Step 4 – Computation of stresses at implant-bone interface when subjected to loading.

Step 1 – Construction of CAD models CAD Geometry Modelling:
The implant system, abutment, screw, restorative crown and bone were built in "AutoCad Inventor 2017" using reverse engineering technique. The model components were further assembled in "SOLIDWORKS 2017" to obtain a complete assembled model. The CAD file forthe implant and prosthetic components were exported as STL file to the finite element software.

Step 2 – Generation of Finite Element Models

a) Finite element program: This program was divided into following steps-

1) Pre-processing: Geometric models were prepared and finite element mesh was superimposed on it by manual meshing orauto meshing
2) Processing – The simultaneous equations were generated and solved by the program
3) Post-processing – Results obtained were viewed graphically as colour patterns.

This study was conducted using ANSYS Software.

b) Three-Dimensional FEM Modelling: The three-dimensional CAD geometry model files were imported into ANSYS Software togenerate finite elements and perform the numerical simulation.

Step 3 – Assigning material properties and application of loading

Boundary condition and constraints: In this study, all the implants and prosthetic components were homogenous, isotropic and linearly elastic. Based on past literature reports material properties for implant components were assigned. Contact analysis defined the load transfer between these different components

Table 1: Material properties of each part of FEA models

Material	Elastic Modulus (MPa)	Poisson's Ratio
Titanium	110000	0.35
Cortical bone	14000	0.30

Cancellous Bone	1370	0.30
Crown	140000	0.28

Loading Conditions:

The range of maximum force applied to the maxillary premolar and molar is 50 N to 900N.Therefore, an average load of 300 N was applied to the model at an angle of 90°and 150 N at an angle of 30° on the occlusal surface of the maxillary premolar and molar.

Step 4 – Computation of stress distribution when subjected to three-dimensional occlusal loading

Finite Element Analysis:

In this study, models were investigated to evaluate the stress distribution. For a direct and systematic comparison, the same material properties, load conditions, boundary conditions and constraints were applied across all models. ANSYS was used to analyse model data and perform the stress analysis.

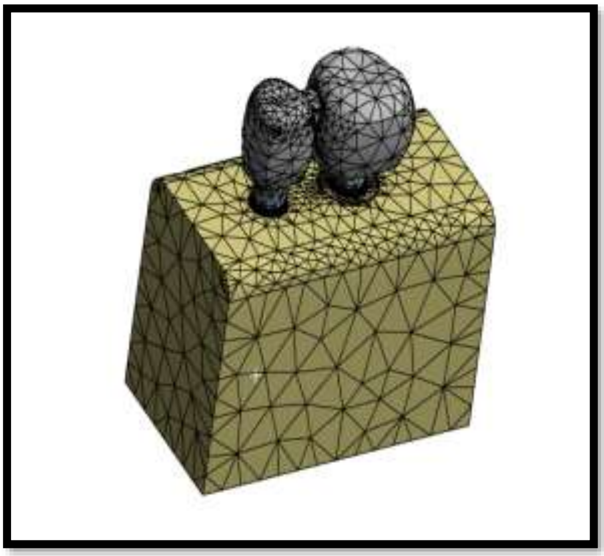


Figure 1 Geometrical value of Model Internal Hexagon (MIH) splinted prosthetic structure model

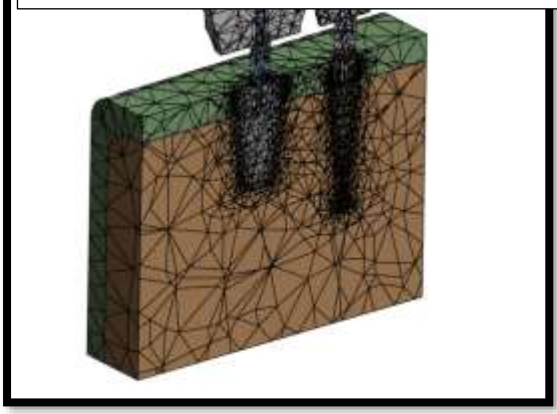


Figure 2 Cross-sectional view of the model generated

Figure 3 Geometrical value of Model Internal Hexagon (MIH) prosthetic structure

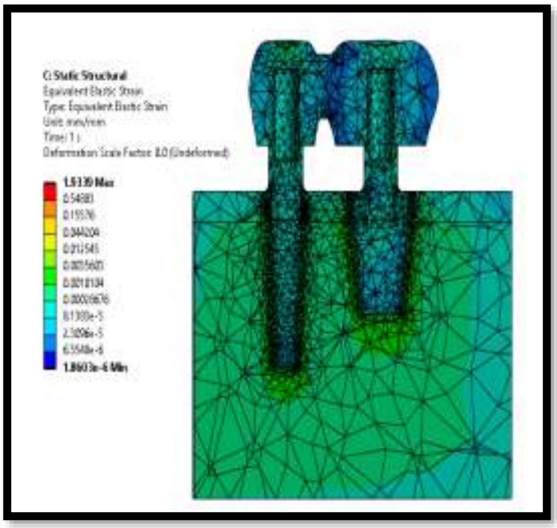


Fig 4 Minimum and maximum principal strains in bone implant cross sections view under vertical load

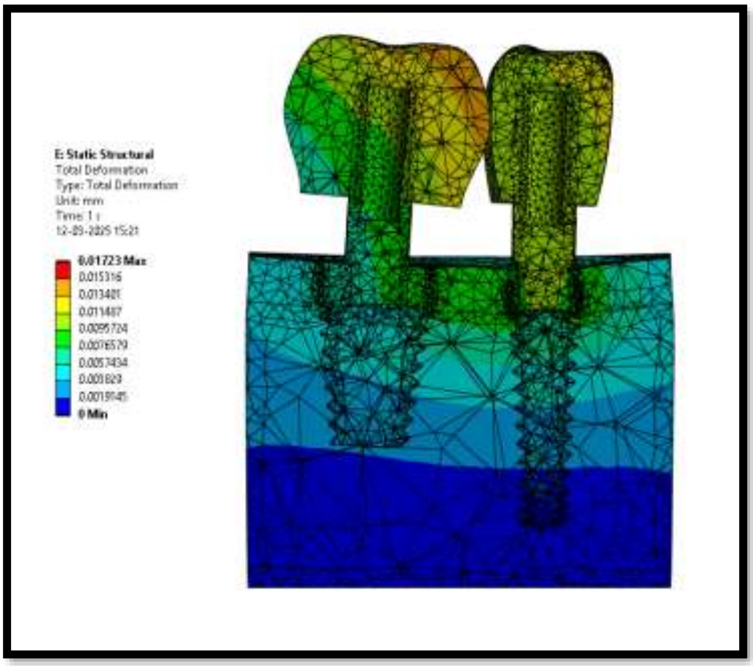


Fig 5 Minimum and maximum principal strains in bone implant cross sections under oblique view of splinted model

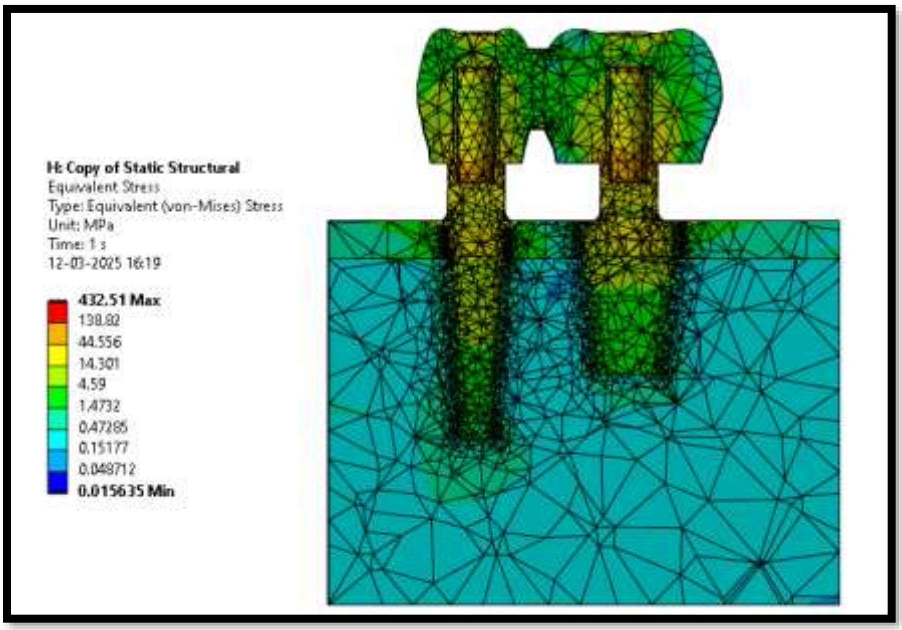
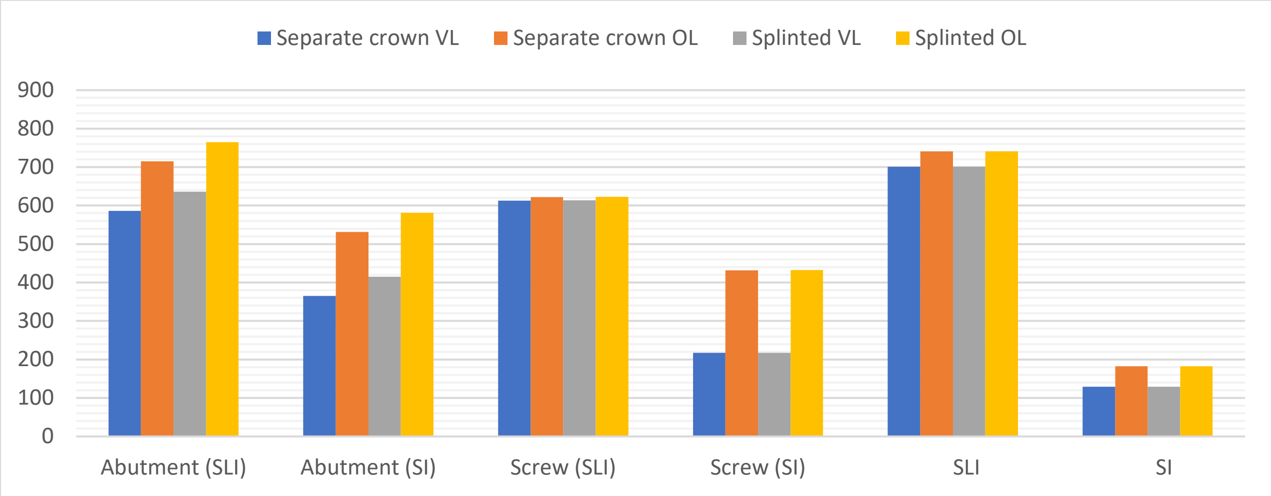


Fig 6 Von mises strain generated after assembly

Results

Table 2 von Mises stress (MPa) on abutment, implant and screw under vertical and oblique loading for separate and splinted crowns

	Separate crown		**Splinted**	
	VL	**OL**	**VL**	**OL**
Abutment (SLI)	386	515	636	765
Abutment (SI)	565	331	415	581
Screw (SI)	613	622	613.4	622.5
Screw (SLI)	217	432	217.1	432.5
SI	701	741	701.0	741.0
SLI	129	182	129.0	182.0



Graph 1 The above chart plotted has forces on X-axis and Maximum Von Mises Stress (MPa) against Y-axis under vertical and oblique forces VL, vertical load OL, oblique load SLI, standard long implant, SI, short implant

In the short and wide implant all the implant components had greater von Mises strains in the abutment, implant and screw compared with those of long and thin implant. The main difference was seen that less stress was presented on the screw, abutment and implant under vertical load.
As seen in the Graph 1 under oblique load, which is critical loading the stresses are generated more. The maximum principal stress was concentrated on the bone around implant neck.
As the splinting of the crowns are put under loading conditions stresses are less than separate crowns in vertical and oblique conditions.

Table 3 von Mises strain (mm/mm) on separate crown and splinted under vertical and oblique loads on abutment, screw and implant

	Separate crown		**Splinted**	
	VL	**OL**	**VL**	**OL**
Abutment (SLI)	0.00788	0.0591	0.00908	0.06029
Abutment (SI)	0.00574	0.0487	0.00694	0.04991
Screw (SLI)	0.01225	0.0191	0.01021	0.01591
Screw (SI)	0.00346	0.0040	0.00288	0.00330
SLI	0.00645	0.0067	0.00597	0.00617
SI	0.00573	0.0054	0.00525	0.00490

Abutment displacement was consistently higher in the oblique load direction compared to the vertical load direction for both standard long implant and short implant
Screw displacement was significantly lower than abutment displacement.
The SLI components showed slightly higher displacement than the SI components. Overall displacement values were minimal, indicating high stability in both restoration types when subjected to vertical and oblique loads.

Discussion

Finite element analysis (FEA) has become a crucial tool in this endeavor, simulating clinical scenarios to evaluate stress distribution within implant systems. These finite element analysis studies have demonstrated that implant geometry, including thread profile and shape, plays a significant role in determining how occlusal loads are distributed across the supporting bone tissue. Finite element analysis especially for challenging clinical situations, can predict the final microstrain-stress distribution in the corresponding part before each surgery, assisting the clinician with the treatment plan.[18]

Micromotion is an important parameter that has received relatively little attention in the field of prosthodontic implants. This parameter needs to be addressed for long-term success of implants as it can predict the primary stability of implants within the bone and the secondary stability of their components.Micromotion has been regarded as one of the parameters that contribute to the formation of microgaps between the mating surfaces of dental implants. Occlusal forces produced during clenching, chewing and jiggling movements are typically transferred through dental implant systems, resulting in movement between the implants and the abutments.[22]

Considering stress concentrations around the implants, Chou et al[23] concluded that the highest stress concentrations during implant loading were found in the cortical section around the upper part of the implant, no matter of implant length or width. However, conflicted opinions exist if short implants and their surrounding bone are subjected to higher stress concentrations compared with standard length implants. Although 83% of the authors report higher stress concentrations with the use of short implants, 38% state that implant length only plays a minor role when considering stress concentrations operating on the implant-bone interface.[6–13]

Tepper et al [14] concluded that interfacial stresses are higher with short-thick implants, and the overall stiffness of the bone-implant system is higher than with long-thin implants; moreover, displacements during loading are less extensive. It was shown that implant diameter may be considered a more effective design parameter than implant length to reduce stress concentrations and to avoid an overload of periimplant bone.[19–21]

Nishioka et a[l24] suggested the implant diameter to affect stress peaks at the cortical bone but not at the cancellous region, whereas stress levels and distribution at the trabecular bone-implant interface are primarily influenced by implant length.[25]

Desai et al [30] measured less stress concentrations around a well osseointegrated 7-mm implant (98.2% BIC) compared with a 13-mm implant with only 53.0% BIC. This was proven by other authors who stated that in situations of osseointegration, the implant length has little influence on stress concentrations, whereas implant diameter does. Implants placed in an augmented sinus were evaluated by Saidin et al,[28] and the reduction of stress concentrations around native bone by increasing diameter were primarily a result of the increased BIC area.

Implant length should exceed 9.0 mm in type IV bone because of the fact that longer implants were reported to have a biomechanical advantage over short ones in this situ.[31] Enough available bone volume in the area of planned implant placement is crucial but bone quality hat describes the internal architecture and reflects the resistance of bone, also influences therapeutic approach. Significantly more implants get lost in regions of weak bone (D4) than in bone with more cortical thickness D1, D2, or D3.

Vargas-Moreno [44] showed that the use of threaded implants decreased the bone stress and sliding distance obviously to 30% compared with nonthreaded (cylindrical and stepped) implants. Furthermore, Shah et al[43] report that nonthreaded implant segments do not ensure adequate osseointegration as interfacial load is too low.

According to an FEA of Schmidt et al,[46] double and triple threaded implants as well as implants with an increased thread helix angle constitute decreased stability. Regarding thread height and width, the optimal thread height is suggested between 0.34 and 0.5 mm and thread width between 0.18 and 0.3 mm. Thread width being less sensitive to maximum stresses than thread height.

The model used in the present study implied several assumptions regarding the simulated structures. The structures in this model were all assumed to be homogenous and isotropic and to possess linear elasticity. In reality, the materials used, particularly the plastics and living tissues are much more dynamic.

Investigating peri-implant bone levels around splinted and non splinted implants, reported that splinting short implants (<6mm) might limit marginal bone loss. In contrast, Datte et al[42] reported that splinted short implants (5/7mm) had significantly greater marginal bone loss than non splinted short implants.

Tribst et al[39] evaluated the stress on implants of the same diameter and different lengths placed adjacent, corresponding to 2 premolars and 1 molar tooth. They concluded that, in splinted prostheses, the stress from the implant and abutment in the molar region decreased and that better stress distribution was achieved compared with nonsplinted prostheses

Limitations of the present study include the assumptions that 100% osseointegration occurred between bone and implant, the simplistic boundary conditions in the model

and that no long-term bone changes occurred. However, the approximately 50% to 80% bone-implant contact commonly observed in implants is considered to be clinically successful.

Keeping the abutment connections the same and examining the effect of pitch, self-tapping features, and spiral numbers may be the subject of an additional study.

Conclusion

Within the limitations of the study, these are findings

1. Optimized implant design shows maximum strain at the implant abutment interface.
2. Implant restorations when splinted have less rate of stress distribution than non-splinted restorations.
3. Angled loads in contrast to vertical loads induce greater moment force on implant.

References

1. Misch CE, Dietsh-Misch F, Hoar J, Beck G, Hazen R, Misch CM. A bone quality- based implant system: first year of prosthetic loading. J Oral Implantol. 1999;25(3):185-97.
2. Cehreli M, Duyck J, De Cooman M, Puers R, Naert I. Implant design and interface force transfer. A photo elastic and strain-gauge analysis. Clin. Oral Impl. Res. 15, 2004; 249–257.
3. Misch CE, Steignga J, Barboza E, Misch-Dietsh F, Cianciola LJ, Kazor C. Short dental implants in posterior partial edentulism: a multicenter retrospective 6-year case series study. J Periodontol. 2006 Aug;77(8):1340-7.
4. Li T, Kong L, Wang Y, Hu K, Song L, Liu B, Li D, Shao J, Ding Y. Selection of optimal dental implant diameter and length in type IV bone: a three-dimensional finite element analysis. Int J Oral Maxillofac Surg. 2009 Oct;38(10):1077-83.
5. Anitua E, Tapia R, Luzuriaga F, Orive G. Influence of implant length, diameter, and geometry on stress distribution: a finite element analysis. Int J Periodontics Restorative Dent. 2010 Feb;30(1):89-95.
6. Faegh S, Müftü S. Load transfer along the bone-dental implant interface. J Biomech. 2010 Jun 18;43(9):1761-70.
7. Okumura N, Stegaroiu R, Kitamura E, Kurokawa K, Nomura S. Influence of maxillary cortical bone thickness, implant design and implant diameter on stress around implants: a three-dimensional finite element analysis. J Prosthodont Res. 2010 Jul;54(3):133-42.
8. Guarnieri, R., Di Nardo, D., Di Giorgio, G., Miccoli, G., & Testarelli, L. (2021). Evaluation of peri-implant tissues condition after 10–15 years of loading in treated chronic periodontitis patients attending a private practice setting: A retrospective study. Clinical Oral Implants Research, 32(4), 422–436.
9. Sivolella S, Stellini E, Testori T, Di Fiore A, Berengo M, Lops D. Splinted and unsplinted short implants in mandibles: a retrospective evaluation with 5 to 16 years of follow-up. J Periodontol. 2013 Apr;84(4):502-12.
10. Yilmaz B, McGlumphy E, Purcell B. An alternative direct technique for the fabrication of an implant-supported, screw-retained fixed interim restoration. J Prosthet Dent. 2012 Feb;107(2):137-9.

11. Toniollo MB, Vieira LJP, Dos Santos Sá M, Macedo AP, Melo JP de Jr, Terada ASSD. Stress distributionof three-unit fixed partial prostheses (conventional and pontic) supported by three or two implants: 3D finite element analysis of ductile materials. Comput Methods Biomech Biomed Engin 2019;22(7):706–12.
12. Reilly DT, Burstein AH. The elastic and ultimate properties of compact bone tissue.J Biomech. 1975;8(6):393-405.
13. Geng JP, Tan KB, Liu GR. Application of finite element analysis in implant dentistry: a review of the literature. J Prosthet Dent. 2001 Jun;85(6):585-98.
14. Tepper G, Haas R, Zechner W, Krach W, Watzek G. Three-dimensional finite element analysis of implant stability in the atrophic posterior maxilla: a mathematical study of the sinus floor augmentation. Clin Oral Implants Res. 2002 Dec;13(6):657-65.
15. Akça, Kıvanç & Iplikçioğlu, H. (2002). Finite element stress analysis of the effect of short implant usage in place of cantilever extensions in mandibular posterior edentulism. Journal of oral rehabilitation. 29. 350-6.
16. 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 Mar-Apr;21(2):195-202.
17. 17Rubo, J.H. and Souza, E.A. (2008) Finite-Element Analysis of Stress in Bone Adjacent to Dental Implants. Journal of Oral Implantology, 34, 248-255.
18. Bergkvist, G., Simonsson, K., Rydberg, K., Johansson, F. and Dérand, T. (2008), A Finite Element Analysis of Stress Distribution in Bone Tissue Surrounding Uncoupled or Splinted Dental Implants. Clinical Implant Dentistry and Related Research, 10: 40-46.
19. Huang YC, Huang YC, Ding SJ. Primary stability of implant placement and loading related to dental implant materials and designs: A literature review. J Dent Sci. 2023 Oct;18(4):1467-1476.
20. Ding X, Liao SH, Zhu XH, Zhang XH, Zhang L. Effect of diameter and length on stress distribution of the alveolar crest around immediate loading implants. Clin Implant Dent Relat Res. 2009 Dec;11(4):279-87.
21. Pessoa RS, Vaz LG, Marcantonio E Jr, Vander Sloten J, Duyck J, Jaecques SV. Biomechanical evaluation of platform switching in different implant protocols: computed tomography-based three-dimensional finite element analysis. Int J Oral Maxillofac Implants. 2010 Sep-Oct;25(5):911-9.
22. Nissan J, Ghelfan O, Gross M, Chaushu G. Analysis of load transfer and stress distribution by splinted and unsplinted implant-supported fixed cemented restorations. J Oral Rehabil. 2010 Sep;37(9):658-62.
23. Chou HY, Müftü S, Bozkaya D. Combined effects of implant insertion depth and alveolar bone quality on periimplant bone strain induced by a wide-diameter, short implant and a narrow-diameter, long implant. J Prosthet Dent. 2010 Nov;104(5):293-300
24. Nishioka, Renato Sussumu DDS, MS, PhD*; de Vasconcellos, Luis Gustavo Oliveira DDS, MS†; de Melo Nishioka, Gabriela Nogueira‡. Comparative Strain Gauge Analysis of External and Internal Hexagon, Morse Taper, and Influence of Straight and Offset Implant Configuration. Implant Dentistry 20(2):p e24-e32, April 2011.
25. Perelli M, Abundo R, Corrente G, Saccone C. Short (5 and 7 mm long) porous implant in the posterior atrophic mandible: a 5-year report of a prospective study. Eur J Oral Implantol. 2011 Winter;4(4):363-8.
26. Chang SH, Lin CL, Lin YS, Hsue SS, Huang SR. Biomechanical comparison of a single short and wide implant with monocortical or bicortical engagement in the atrophic posterior maxilla and a long implant in the augmented sinus. Int J Oral Maxillofac Implants. 2012 Nov-Dec;27(6):e102-11.
27. de Carvalho NA, de Almeida EO, Rocha EP, Freitas AC Jr, Anchieta RB, Kina S. Short implant to support maxillary restorations: bone stress analysis using regular and switching platform. J Craniofac Surg. 2012 May;23(3):678-81.
28. Saidin, S., Abdul Kadir, M. R., Sulaiman, E., & Abu Kasim, N. H. (2012). Effects of different implant–abutment connections on micromotion and stress distribution: Prediction of microgap formation. Journal of Dentistry, 40(6), 467–474.
29. Monje A, Chan HL, Fu JH, Suarez F, Galindo-Moreno P, Wang HL. Are short dental implants (<10 mm) effective? a meta-analysis on prospective clinical trials. J Periodontol. 2013 Jul;84(7):895-904.
30. Desai SR, Singh R, Karthikeyan I. 2D FEA of evaluation of micromovements and stresses at bone-implant interface in immediately loaded tapered implants in the posterior maxilla. J Indian Soc Periodontol. 2013 Sep;17(5):637-43.
31. Monje A, Chan HL, Fu JH, Suarez F, Galindo-Moreno P, Wang HL. Are short dental implants (<10 mm) effective? a meta-analysis on prospective clinical trials. J Periodontol. 2013 Jul;84(7):895-904.
32. Ohyama T, Uchida T, Shibuya N, Nakabayashi S, Ishigami T, Ogawa T. High bone- implant contact

achieved by photofunctionalization to reduce periimplant stress: a three-dimensional finite element analysis. Implant Dent. 2013 Feb;22(1):102-8.

33. Garaicoa-Pazmiño C, Suárez-López del Amo F, Monje A, Catena A, Ortega-Oller I, Galindo-Moreno P, Wang HL. Influence of crown/implant ratio on marginal bone loss: a systematic review. J Periodontol. 2014 Sep;85(9):1214-21.
34. TakahashiJMFK, Dayrell AC, ConsaniRLX, de Arruda Nóbilo MA, Henriques GEP, Mesquita MF. Stressevaluation of implant-abutment connections under different loading conditions: a 3D finite element study. J OralImplantol. 2015;41(2):133–7.
35. Moriwaki H, Yamaguchi S, Nakano T, Yamanishi Y, Imazato S, Yatani H. Influence of implant length anddiameter, bicortical anchorage, and sinus augmentation on bone stress distribution: Three-dimensional finite element analysis. Int J OralMaxillofac Implants 2016;31(4):e84-9
36. Fan T, Li Y, Deng W-W, Wu T, Zhang W. Short implants (5 to 8 mm) versus longer implants (>8 mm)withsinus lifting in atrophic posterior maxilla: A meta-analysis of RCTs. Clin Implant Dent Relat Res. 2017;19(1):207–15.