International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

Impact Of Alveolar Bone Density On Dental Implant Survival Rate: An Experimental Study.

Arshad Jamal Sayed[1]
[1]Associate Professor, Department of Periodontology and Implant Dentistry, College of Dentistry, Qassim University, Saudi Arabia, a.sayed@qu.edu.sa, ORCID: 0000 0003 4785 4911

Abstract:
Background: *Impaired bone quality significantly impacts dental implants' prognosis because it alters implant stability, one of the most crucial requirements for successful implants. According to density, Carl E. Misch divided bone quality into four categories: D1, D2, D3, and D4. The strongest of all is Type D1, with 80% stronger trabeculae; Type D2 has a combination of porous and dense bone, with trabeculae that are 40%–60% stronger than Type D3; Type D4 has poor density and trabeculae that are 10 times weaker than Type D1.*
Purpose: The Present finite element analysis (FEA) assessed the influence of bone densities (D1, D2, D3, and D4) on the survival rate of implants by assessing the stress-strain distribution and displacement at the peri-implant area and on the implant system.
Materials and Methods: *A data library at the Qassim University Dental Clinic was searched for Cone Beam CT scans. The volume bone mineral density of cortical and cancellous bone related to its density (HU units) was established to get unique bone qualities. The cortical and cancellous volume percentages were estimated as per available literature and superimposed with the attained varying percentages to mimic altered bone qualities (D1, D2, D3, and D4). All 4 Groups were subjected to Finite Element Analysis using ANSYS (ANSYS14.5, USA). Meshes and modelling geometric shapes for the required components, boundary conditions were employed, and the outcomes were recorded and analysed for Von Mises Stress and deformation on the Implant system and peri-implant bone on all 4 models on a vertical load of 140N.*
Results: *Maximum von Mises Overall stress was observed on D4 model (139.55MPa, soft bone), and less stress was noted on the D1, D2, and D3 Models. Maximum cortical bone stress (17.43 MPa) was noted on softer bone (D4), where minimum thickness cortical bone was available. Maximum Implant system stress was observed on the D4 model implant (74.79 MPa) due to poor quality bone as compared to the D1, D2, and D3 models (37.09 MPa, 54.21 MPa, and 45.27 MPa). Overall deformation/displacement was observed on soft bone D4 model (12.2 µm) as compared to harder bone D1, D2 & D3 models (5.6 µm, 5.5 µm, and 5.1 µm) respectively.*
Conclusions: *The current study's findings recommend that bone quantity and quality should be assessed before implant placement and loading are planned. Implant planning should be avoided in softer bone (D4) situations or done with the greatest restraint, especially in immediate implant placement. D2 or D3 bone quality is preferred for longer-lasting implants.*
Keywords: *Dental implant, bone quality, finite element analysis, bone density, implant survival*

INTRODUCTION:

The implant survival rate is influenced by several variables, such as implant type and surface characteristics(1), implant geometry, implant design (2), bone loss related to peri-implantitis (3), implant number, and position (4,5). The location where an implant is placed and its tissue response (6), patient selection, systemic conditions, risk factors (smoking, uncontrolled diabetes mellitus (3,7,8)), and the effects of traumatic occlusal forces on implants (9) are all receiving increased attention lately. Additionally, jawbone quantity and quality, osseointegration, and bone-to-implant contact are critical factors in implant placement and loading protocols that affect the primary stability of implants (9–12). An implant's favourable, consistent osseointegration results from the surrounding bone providing primary support. As it concerns bone structure, cancellous bone is related to the blood supply, whereas cortical bone is an important component that influences the primary stability of implant placement (13). Impaired bone quality significantly impacts dental implants' prognosis because it alters implant stability, which is one of the most crucial requirements for successful implants (14). If the gaps between the wall of osteotomy and the implant post-surgical preparation are minimal, the implant remains immobilized during the period of bone repair (15,16). This is especially important if the implant is to be placed in a surgical site in the posterior regions in one stage or if it is to be implanted there and then immediately restored to function. Compared to healed sites (2.4%), fresh extraction sites had a greater implant failure rate (4.3%), according

to a systematic and meta-analysis evaluation. These findings include both anterior and posterior implants, and the review did not address the distinction between the two regions (anterior vs. posterior) (17).
According to density, Carl E. Misch divided bone quality into four categories: D1, D2, D3, and D4. This categorization distinguished them based on the size of the cancellous bone's trabecular spaces and the cortical-to-cancellous bone ratio. These factors affect the bone-to-implant contact (BIC), which in turn assumes the implants' primary stability and micromotion (18,19). The mandibular anterior region is typically associated with Type D1, which has a greater survival rate based on the Misch bone density classification. Type D2 can be observed in the posterior mandibular region, Type D3 in the maxillary anterior region, and Type D4, which is the least common, in the maxillary posterior tooth region. The strongest of all is Type D1, with 80% stronger trabeculae; Type D2 has a combination of porous and dense bone, with trabeculae that are 40%–60% stronger than Type D3; Type D4 has poor density and trabeculae that are 10 times weaker than Type D1 (20,21). Several independent groups have reported different failure rates related to bone quality and quantity. Soft bone densities (D4) had higher tendency (65% - 78%) for implant failure rated and early loading implants (22,23). The failure rate in moderate bone densities was reported by Johns et al. to be 3%, but in the lowest bone densities it was 28% (24). Since the existence of D4 type bone in the maxillary posterior region as opposed to the mandibular region, numerous studies have shown increased rates of implant failure in this location (25–27).
Aging and systemic diseases affecting the quality of bone also needs to be assessed while planning the implants. According to a long-term retrospective research, individuals older than 60 had a greater rate of implant failure (28). Elderly patients may have worse bone quality and slower wound healing, which could change the tissue's reaction to implant insertion and increase the risk of failure (29). Research suggests that while osteoporosis is not an absolute contra-indication for implant failure, several steps can be taken to lower the risk of implant failure. These include extending the implant's osseointegration period and using a specific surgical technique before prosthesis insertion (30,31). Reduced bone-implant contact during early bone healing in osteoporosis was observed (32).
These contradictory results made the clinicians difficult while deciding to go for implants with compromised bone quality or quantity. This is a major challenge when you plan for an immediate implant. To predict the dispersal of stress and strain in the peri-implant area, bone density is an important factor. This factor influences bone remodelling and modelling, which in turn affects the success or failure rates of dental implants. Additionally, because of stress-shielding events, aseptic implant loosening, and marginal bone loss are brought on by the differential in stiffness between implant material and peri-implant bone. Hence, this FEA aimed to assess the influence of bone densities (D1, D2, D3, and D4) on the survival rate of implants by assessing the stress-strain distribution and displacement at the peri-implant area and on the implant system.

MATERIAL AND METHODS:

CBCT imaging acquisition and Processing: Cone Beam CT scans at Qassim University Dental Clinic's data library were searched. The scans' field of view was 15-12 mm, covering mandibular arches. To do the analysis, a CBCT image with the missing mandibular molar teeth and sufficient bone quantity was chosen. The Blue-sky Bio Implant planning (Germany) program was used to reconstruct the CBCT images at a thickness of one millimetre after they were exported as DICOM (digital imaging and communication in medicine) files. The 2D image in the DICOM files is converted to a complete 3D solid model. slices of voxel size 0.125 mm. For the cortical and cancellous bones, a 3D graphic model will be created and saved in Stereolithography (STL) format. GEOMAGICS reverse engineering is used to generate a solid three-dimensional model from CBCT scans of mandibular 3D models.
Acquisition of bone qualities: To get unique bone qualities, the volume bone mineral density of cortical and cancellous bone related to its density (HU units) was established to get distinctive bone qualities (18,33,34). The cortical and cancellous bone volume percentages were estimated (35) (Table 1) as per available literature and superimposed with the attained varying percentages to mimic altered bone qualities (D1, D2, D3, and D4), as displayed in Figure 1.
Table 1: Cortical and cancellous bone percentile in distinctive bone types.

	Cortical bone volume	Cancellous bone volume
D1	80%	20%
D2	70%	30%
D3	45%	55%

D4	20%	40%

Virtual implant choice and positioning in the model: Mandibular missing molar tooth, based on the space available for implants and following the Surgical guide instructions, a standard implant of 5.1mm ×11.5 mm was chosen and with standardization for positioning, 4 groups were created with atypical bone densities (D1, D2, D3, and D4) as follows:

Model D1: Mandibular model with D1 bone density with molar Implant **(Fig. 1, a)**.
Model D2: Mandibular model with D2 bone density with molar Implant **(Fig. 1, b)**.
Model D3: Mandibular model with D3 bone density with molar Implant **(Fig. 1, c)**.
Model D4: Mandibular model with D4 bone density with molar Implant **(Fig. 1, d)**.

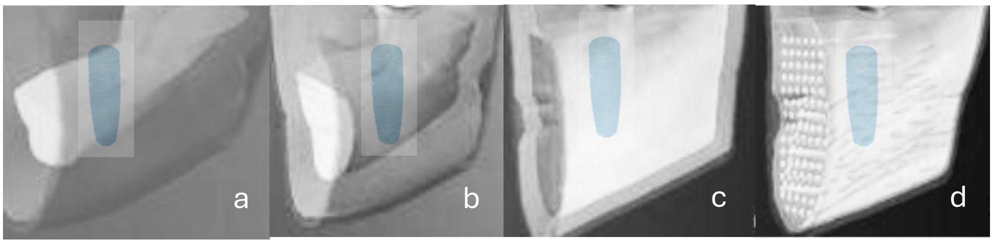

Figure 1,Mandibular Model with Implant superimposed. a-D1 model, b-D2 model, c-D3 model, d-D4 model

The precise geometric measurements, expressed in millimetres, of length, diameter, and macro-micro thread configuration, are taken from the implant library or manufacturer specifications. Using 3-matic software, a CAD model of the dental implant is constructed. (Figure 2, a to f).

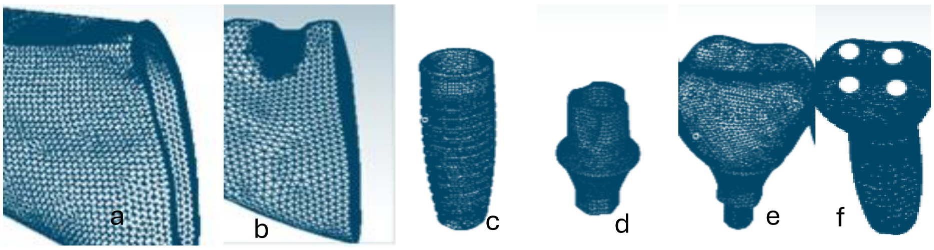

Figure 2, Model of the dental implant using 3-matic software. a-cortical bone, b-cancellous bone, c-implant body, d-implant abutment, e-implant crown, f- 140N vertical implant loading at 4 cusp points.

Finite Element Analysis model: The STL files of the mandibular bone segment with the prosthesis and the characteristics of the implants and bone (D1, D2, D3, and D4 FEA models) are imported using ANSYS (ANSYS14.5,USA). Making meshes and modelling geometric shapes for the required components, boundary conditions are employed, and the outcomes are recorded and analysed (Table 2). All of the constraints of the material (bone and implant) from the literature are provided, such as the modulus of elasticity, Poisson's ratio, and coefficient of friction (36–39), (Table 3).

Models	Elements	Nodes
Model D1	783431	895273
Model D2	649979	776296
Model D3	650595	778282
Model D4	660118	779119

Table 2: FEA Analysis Elements and Nodes for Implant Models (37,38)

Materials	Young's Modulus(GPa)	Poisson's Ratio
Implant (Titanium)	110	0.35
Crown (Porcelain)	68.9	0.28
Cortical Bone	13.7	0.30
Cancellous Bone D1	13.7	0.30
Cancellous Bone D2 & D3 (36,39)	1.37	0.3
Cancellous Bone D4 (36,39)	0.231	0.3

Table 3: Material Properties for FEA analysis

Results: The results of Finite element analysis were analyzed as overall stress, cortical and cancellous bone stress, connection screw stress, crown system stress, implant system stress, abutment stress, and overall deformation (µm) (Table 4).
Overall Stress: On vertical load of 140N on the molar implant maximum von Mises stress was observed on D4 model (139.55MPa, soft bone), and less stress was noted on D1, D2, and D3 Models.
Cortical Bone Stress: Maximum Von Mises stress (17.43 MPa) was noted on softer bone (D4) where minimum thickness cortical bone was available. Cortical bone stress was higher for D1 (15.95MPa) where cortical bone was thickest as compared to D2 and D3 (13.79MPa and 12.97 MPa).

On Vertical Load 140N	Model D1	Model D2	Model D3	Model D4
Overall Stress (MPa)	54.47	69.77	53.64	139.55
Cortical Stress (MPa)	15.95	13.79	12.97	17.43
Cancellous Stress (MPa)	3.61	5.39	4.63	8.42
Implant system Stress (MPa)	37.09	54.21	45.27	74.79
Abutment stress	45.19	60.08	45.80	85.28
Crown Stress (MPa)	38.73	43.09	38.79	113.80
Overall deformation (**µm**)	5.6	5.5	5.1	12.2

Table 4: Maximum von Mises Stress on Vertical Loading (140N)
Cancellous Bone Stress: Von Mises stress was minimum with D1 model (3.6 MPa) where no or minimum cancellous bone was present. The highest stress was observed on a softer bone model (D4, 8.5 MPa) as compared to D2 and D3 (5.39 MPa and 4.63 MPa).
Implant system stress: Maximum Von Mises stress was observed on D4 model implant (74.79 MPa) due to poor quality bone as compared to D1, D2 and D3 models (37.09 MPa, 54.21 MPa and 45.27 MPa).
Implant abutment and Crown system Stress: Highest stress was noted on soft bone model (D4) for abutment stress (85.28 MPa) and crown system (113.80 MPa) and least stress was noted hard bone D1 model (abutment - 45.19 MPa, crown - 38.73 MPa) and moderate stress for D2 and D3 models.
Overall deformation: On vertical loading of 140N load, maximum displacement was observed on soft bone D4 model (12.2 µm) as compared to harder bone D1, D2 & D3 models (5.6 µm, 5.5 µm and 5.1 µm) respectively.

DISCUSSIONS:
The current finite element analysis (FEA) study examined the patterns of stress distribution in implants, the implant system, and four distinct alveolar bone density configurations under conditions of vertical loading (D1, D2, D3, & D4). Higher stress and strain patterns were seen in softer bone forms (D4). Due to its low quality, D4 bone was more likely to fail an implant when subjected to 140N forces and vertical loading. For stronger bone configurations (D1, D2, & D3), the overall stress, the stress on the cortical and cancellous bone, and the implant system (implant body, abutment, and crown) were all satisfactory. Different failure rates have been noted by multiple independent groups while referring to bone quality and quantity. According to Schnitman et al., the implant survival percentage over three years varied from 100% in the anterior mandible to 78% in the posterior maxilla (25). The 36-month clinical result of an endosteal was reported by Brass LS and Triplet RG (1991), who also analysed the success rate of implants in the maxilla at 93.4% and in the mandible at 97.2%. They concluded that implant failure rates were mostly caused by poor bone quality in the maxillary region, with bone quantity demonstrating less significance (26). In softer bone types, 78% of implant failures for implant-supported overdentures were noted by Engquist et al (22). According to Friberg et al., 66% of resorbed maxilla with soft bone experienced implant failure(23). Hermann and colleagues discovered a substantial correlation between implant failures and patient variables, such as bone quality. This correlation was particularly evident when inadequate bone volume was present, which accounted for 65% of implant failures (40).
However, research has also shown that early-loading implants and high-quality bone have greater failure rates. Early loading failures were documented by Zarb and Schmitt in 3.3% of predominantly edentulous mandibular patients with good grade bone (41). Similarly, Naert and Quirynen found that 2.5% of patients who were partially edentulous and had early loading in high-quality bone failed (42). These

findings suggest along with the quality of bone, other factors such as quantity, timing of implant placement, and loading equally play a significant role in its success.

CONCLUSIONS:

The current study's findings recommend that before planning for implant placement and loading, bone quantity and quality should be assessed. In addition, other factors that could interfere, like implant characteristics, traumatic occlusal forces, and systemic disorders that impact bone quality and healing, should also be taken into account. Implant planning should be avoided in softer bone (D4) situations or done so with highest restraint. D2 or D3 bone quality is preferred for longer-lasting implants.

Patents: None.
Funding: None.
Conflicts of Interest: None.
Institutional Ethical (IRB) Approval: Obtained

REFERENCES:

1. Grusovin MG, Coulthard P, Worthington HV, George P, Esposito M. Interventions for replacing missing teeth: maintaining and recovering soft tissue health around dental implants. Cochrane Database Syst Rev. 2010 Aug 4;2010(8):CD003069.
2. Mavrogenis AF, Dimitriou R, Parvizi J, Babis GC. Biology of implant osseointegration. J Musculoskelet Neuronal Interact. 2009;9(2):61–71.
3. Meza Maurício J, Miranda TS, Almeida ML, Silva HD, Figueiredo LC, Duarte PM. An umbrella review on the effects of diabetes on implant failure and peri-implant diseases. Braz Oral Res. 2019;33(suppl 1):e070.
4. Fransson C, Lekholm U, Jemt T, Berglundh T. Prevalence of subjects with progressive bone loss at implants. Clin Oral Implants Res. 2005 Aug;16(4):440–6.
5. Fransson C, Wennström J, Berglundh T. Clinical characteristics at implants with a history of progressive bone loss. Clin Oral Implants Res. 2008 Feb;19(2):142–7.
6. Cardaropoli G, Araújo M, Lindhe J. Dynamics of bone tissue formation in tooth extraction sites. An experimental study in dogs. J Clin Periodontol. 2003 Sep;30(9):809–18.
7. Lindhe J, Meyle J, Group D of European Workshop on Periodontology. Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. J Clin Periodontol. 2008 Sep;35(8 Suppl):282–5.
8. Anner R, Grossmann Y, Anner Y, Levin L. Smoking, diabetes mellitus, periodontitis, and supportive periodontal treatment as factors associated with dental implant survival: a long-term retrospective evaluation of patients followed for up to 10 years. Implant Dent. 2010 Feb;19(1):57–64.
9. Bertolini MM, Del Bel Cury AA, Pizzoloto L, Acapa IRH, Shibli JA, Bordin D. Does traumatic occlusal forces lead to peri-implant bone loss? A systematic review. Braz Oral Res. 2019;33(suppl 1):e069.
10. Soman DC, Almuhrij A, Alghusen N, Alsubaie FA, Aljamal M, Alrasheed R. CBCT Analysis of Alveolar Bone Dimensions in Mandibular Posterior Teeth: A Preliminary Study.,. Indian J Appl Res [Internet]. 2019 Nov 1 [cited 2020 Jun 30];9(10). Available from: http://www.worldwidejournals.net/index.php/IJAR/article/view/848
11. Elias CN, Rocha FA, Nascimento AL, Coelho PG. Influence of implant shape, surface morphology, surgical technique and bone quality on the primary stability of dental implants. J Mech Behav Biomed Mater. 2012 Dec;16:169–80.
12. Esposito M, Grusovin MG, Maghaireh H, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. Cochrane Database Syst Rev. 2013 Mar 28;2013(3):CD003878.
13. Lekholm, U., Zarb, GA., Albrektsson, T. Patient selection and preparation. Tissue integrated prostheses. In chicago: Quintessence Publishing Co; 1985. p. 199–209.
14. sayed AJ, safia Shoeb Shaikh, Shoeb Yakub Shaikh, Mohammed Abid Hussain. Inter Radicular Bone Dimensions in Primary Stability of Immediate Molar Implants - A Cone Beam Computed Tomography Retrospective Analysis. Saudi Dent J. 33(1).
15. Sayed AJ, Garg KK, Mohan SR, Khan Tareen SU, Shiva Shankar B, Omran MH. Influence of Implant Location, Number, and Design in Ischemic Zone for Implant Prosthesis Success Rate: A Comparative Three-Dimensional Finite Element Analysis. Cureus. 2024 Feb;16(2):e53881.
16. Rutkowski JL. Fundamentals of Implant Dentistry: Prosthodontic Principles. Beumer J III, Faulkner RF, Shah KC, Moy PK. Hanover Park, Ill: Quintessence Publishing, 2015. J Oral Implantol. 2015 Jun;41(3):343.
17. Chrcanovic BR, Albrektsson T, Wennerberg A. Dental implants inserted in fresh extraction sockets versus healed sites: a systematic review and meta-analysis. J Dent. 2015;43(1):16–41.
18. Misch CE. Contemporary implant dentistry. Int J Oral Maxillofac Surg. 2008;37:3–556.
19. Hsu JT, Huang HL, Chang CH, Tsai MT, Hung WC, Fuh LJ. Relationship of three-dimensional bone-to-implant contact to primary implant stability and peri-implant bone strain in immediate loading: microcomputed tomographic and in vitro analyses. Int J Oral Maxillofac Implants. 2013;28(2):367–74.
20. Chong L, Khocht A, Suzuki JB, Gaughan J. Effect of implant design on initial stability of tapered implants. J Oral Implantol. 2009;35(3):130–5.
21. Sreerama R, Kolluru KC, Gottumukkala V, Innampudi CK, Konathala JR, Krishnaveni G. Assessment of the Effect of Bone Density on Implant Stability: A Clinical Study. J Pharm Bioallied Sci. 2021 Jun;13(Suppl 1):S297–300.
22. Engquist B, Bergendal T, Kallus T, Linden U. A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. Int J Oral Maxillofac Implants. 1988;3(2):129–34.

23. Friberg B, Sennerby L, Roos J, Lekholm U. Identification of bone quality in conjunction with insertion of titanium implants. A pilot study in jaw autopsy specimens. Clin Oral Implants Res. 1995 Dec;6(4):213–9.
24. Johansson, P. and Strid, K.G. Assessment of Bone Quality from Placement Resistance during Implant Surgery. Int J Oral Maxillofac Implants. 1994;9:279–88.
25. Schnitman PA, Rubenstein JE, Whörle PS, DaSilva JD, Koch GG. Implants for partial edentulism. J Dent Educ. 1988 Dec;52(12):725–36.
26. Bass SL, Triplett RG. The effects of preoperative resorption and jaw anatomy on implant success. A report of 303 cases. Clin Oral Implants Res. 1991;2(4):193–8.
27. Mahesh L, Boquete Castro A, Bhasin MT. The Survival Rate of Posterior Immediate Implants in the Maxilla and Mandible: An Observational Retrospective Study of 158 Dental Implants. Cureus. 15(9):e45579.
28. Moy PK, Medina D, Shetty V, Aghaloo TL. Dental implant failure rates and associated risk factors. Int J Oral Maxillofac Implants. 2005;20(4):569–77.
29. Shirota T, Ohno K, Suzuki K, Michi K. The effect of aging on the healing of hydroxylapatite implants. J Oral Maxillofac Surg Off J Am Assoc Oral Maxillofac Surg. 1993 Jan;51(1):51–6.
30. Tsolaki IN, Madianos PN, Vrotsos JA. Outcomes of dental implants in osteoporotic patients. A literature review. J Prosthodont Off J Am Coll Prosthodont. 2009 Jun;18(4):309–23.
31. Gaetti-Jardim EC, Santiago-Junior JF, Goiato MC, Pellizer EP, Magro-Filho O, Jardim Junior EG. Dental implants in patients with osteoporosis: a clinical reality? J Craniofac Surg. 2011 May;22(3):1111–3.
32. Keller JC, Stewart M, Roehm M, Schneider GB. Osteoporosis-like bone conditions affect osseointegration of implants. Int J Oral Maxillofac Implants. 2004;19(5):687–94.
33. Gulsahi A. Bone Quality Assessment for Dental Implants. In: Turkyilmaz I, editor. Implant Dentistry - The Most Promising Discipline of Dentistry [Internet]. InTech; 2011 [cited 2024 Sep 10]. Available from: http://www.intechopen.com/books/implant-dentistry-the-most-promising-discipline-of-dentistry/bone-quality-assessment-for-dental-implants
34. Giambini H, Dragomir-Daescu D, Nassr A, Yaszemski MJ, Zhao C. Quantitative Computed Tomography Protocols Affect Material Mapping and Quantitative Computed Tomography-Based Finite-Element Analysis Predicted Stiffness. J Biomech Eng. 2016 Sep 1;138(9):0910031–7.
35. Shaker D, Elkhadem A, Abdel Rasoul M, Askar MG. Influence Of Implant Thread's Cross-Sectional Design On The Micromotion Of The Implants In Different Bone Qualities: Finite Element Analysis. Adv Dent J. 2021 Jan 1;3(1):1–11.
36. Holmes DC, Loftus JT. Influence of bone quality on stress distribution for endosseous implants. J Oral Implantol. 1997;23(3):104–11.
37. Lacroix D, Prendergast PJ, Li G, Marsh D. Biomechanical model to simulate tissue differentiation and bone regeneration: application to fracture healing. Med Biol Eng Comput. 2002 Jan;40(1):14–21.
38. Schwartz-Dabney CL, Dechow PC. Edentulation alters material properties of cortical bone in the human mandible. J Dent Res. 2002 Sep;81(9):613–7.
39. Yalçın M, Kaya B, Laçin N, Arı E. Three-Dimensional Finite Element Analysis of the Effect of Endosteal Implants with Different Macro Designs on Stress Distribution in Different Bone Qualities. Int J Oral Maxillofac Implants. 2019;34(3):e43–50.
40. Herrmann I, Lekholm U, Holm S, Karlsson S. Impact of implant interdependency when evaluating success rates: a statistical analysis of multicenter results. Int J Prosthodont. 1999;12(2):160–6.
41. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part III: Problems and complications encountered. J Prosthet Dent. 1990 Aug;64(2):185–94.
42. Naert I, Quirynen M, van Steenberghe D, Darius P. A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. J Prosthet Dent. 1992 Feb;67(2):236–45.