OPEN ACCESS

Saudi Journal of Oral and Dental Research
Abbreviated Key Title: Saudi J Oral Dent Res
ISSN 2518-1300 (Print) | ISSN 2518-1297 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article | **Prosthodontics**

Scientific Rationale of Implant Design: A Review Article

Tushar[1*], Srishti Garg[2], Aditya Chaudhary[3], Anju Aggarwal[4]

[1]BDS, MDS., Senior Lecturer, Department of Prosthodontics, ITS CDSR Muradnagar, Uttar Pradesh, India
[2]BDS, MDS., Consultant Prosthodontist (Dehradun), Uttar Pradesh, India
[3]BDS, MDS., Professor Department of Prosthodontics, Post Graduate Student, Department of Prosthodontics, Crown and Bridge, ITS Dental college, Hospital and Research Centre Greater Noida, Uttar Pradesh, India
[4]BDS, MDS., Professor, Department of Prosthodontics, Crown and Bridge, ITS Dental College, Hospital and Research Centre, Greater Noida, Uttar Pradesh, India

DOI: 10.36348/sjodr.2022.v07i04.001 | **Received:** 15.02.2022 | **Accepted:** 19.03.2022 | **Published:** 09.04.2022

***Corresponding author:** Dr. Tushar
BDS, MDS., Senior Lecturer, Department of Prosthodontics, ITS CDSR Muradnagar, Uttar Pradesh, India

Abstract

There is no one implant system present that is ideal for every condition. Implant design research has been based on increasing the bone implant contact area or functional surface area in order to increase the implant stability and implant survival in poor density bone. Designing of an implant include both Macroscopic and Microscopic features. Macroscopic features include crest module, implant thread geometry and apical design of implant whereas Microscopic features include surface modificationS. This article reviews elements of various dental implant designs currently in use.

Keywords: Dental Implants, Implant Design, Osseointegration, Internal/External Connection SystemS.

INTRODUCTION

Years of research and studies have lead to the increase in chances for long-term implant stability and function [1]. The predictability of long- term success of dental implants have been seen both in removable and fixed dental prosthesis in the past few decades [2, 3]. Studies have shown a multi-year success rates of more than 90% for implantS placed to rehabilitate either fully edentulous or partially edentulous patients [4-6]. However, these success rates tend to vary in different areas of the mouth and in different patients. For example, studies have shown a lower success rate for maxillary implants rather than mandibular implants. To understand the cause of these failures and to overcome these problems various factors have been identified [7, 8]. Factors such as material biocompatibility, implant design and surface, surgical technique and the loading conditions have been shown to influence the implant osseointegration which further effect the long term implant success [9]. Out of the above mentioned factors Available bone volume has been considered an important factor for implant success followed by the available bone density and proposed implant site [10]. Constant modifications in implant body design and implant surfaces have been suggested to increase the success of implant in poor quality bone by these modification have been based around the following rationale.

1. Gaining better anchorage
2. Increase surface area of the implant surface to improve the stress distribution on the surrounding bone
3. This article reviews the design elements of dental implants that can may affect osseointegration along with itS relationship to long-term success.

Implant neck (crest module)

Acc to the composite beam analysis when one out of two materials of dissimilar elastic moduli, are placed together with an intervening material an increase in stress can be observed at the 1st point of contact of the two material, In implant dentistry these 2 material are the bone and the dental implant material and the 1st point of contact is the crystal bone. Hence it is important to design the crest module in such a way that least amount of stress is concentrated on the crystal region reducing the chances of crestal bone loss [11].

The design modifications for the crest module has been done in 2 ways:
1. Having larger diameter crest module than the

implant body.
2. Having a divergent shape instead of a cylindrical design.

These modification aid in reducing the stress on the crestal region. Application of compressive stress on the adjoining bone, seals the osteotomy site and there by prevent the encroachment of bacteria in the implant bone connection site .

The initial implant design promoted a smooth crestal module as it was thought to promote regular arrangement of epithelial tissue around the implant thus providing soft tissue peripheral seal [12, 13]. However studies later showed that smooth surface modules produces more shear stress which can cause bone loss [14] following these studies, rough surface with micro thread design was introduced with the main concept of increase the bone implants contact area as well as converting the unfavourable micro thread shear stress into more favourable compressive stress [15]. Studies have shown that rough surface implant collar design and collars with micro thread design decrease the bone loss around the crestal region [16].

Implant Prosthetic connection

Implant prosthetic connections have been broadly classified into External and Internal hex design. These connection types are classified on the basis of their position in relation to the body of the implant. External prosthetic connectionS have hex placed outside the implant body where as in internal connection, the connection geometry or hex is placed inside the implant body [12]. The external hex which was given by Dr. BRANEMARK function well with the case where multiple implants have to be splinted together. However this design has been found to be disadvantageous in cases of single implant or reduced inter arch space. Additionally, it has been associated with more bone loss due to increased lateral loading [17, 18]. To overcome the disadvantage of external hex design, Internal hex design was introduced by Dr. Linkow, which was further classified as passive fit design and friction fit design. Passive fit design usually incorporate a 45 degree angled internal hex connection compared to friction fit design which has better hermetic seal than passive fit. Friction fit designs have been inspired by the design given by Stephen A morse in (1864) [19, 20].

Chun *et al*., stated in his study that internal hexagon connection distributes stress better than external hexagonal design, due to its deep seating action within the implants body, hence leading to less bone loss [21]. Resende *et al*., demonstrated that Morse taper connection caused less amount of bone loss when compared with external hex design [22]. Caricasulo *et al*., reviewed the implant prosthetic connection influence on marginal bone loss and found that internal hex design with conical connection exhibited lesser bone loss when compared to external hex design [23].

Quaresma *et al*., compared the finite element analysis of an internal connection and conical connection concluding that conical connection design presented less stress on alveolar bone than normal internal hex design [24]. Maeda *et al*., in his study evaluated the stress concentration for internal and external hex implant prosthesis connection and found that when a force of 250 N was applied to both design in axial and non axial direction, internal hex connection transferred forces more centrally and more homogeneous in manner than external hex design [25].

Implant body

Implant body can be classified as:

1. Based on surface characteristics:
    1. Rough
    2. Machined

2. Based on implant length:
    1. Long (more than 10mm)
    2. Short (less than 10mm)

3. Based on surface morphology:
    1. Threaded
    2. Non threaded

Ogawa *et al*., in 2003 and various authors before conducted an animal studies where they found that bone contact area achieved was 50% greater with rough surface implant design as compared to machined surface [26].

Misch and Bidez placed cylindrical implants of different length in 3d model having ideal bone volume and density concluding that an increase in length aids in resisting more of the lateral forces more efficiently [27]. Longer implants are generally preferred but certain anatomic locations such as posterior lingual concavity in mandible, sinus floor approximation in maxillary, root dilaceration of adjacent tooth, nerve position, etc can cause difficulty in placing longer implants. To avoid these difficulties short implants were introduced [28, 29]. With an average success rate of 80.3%. Naert *et al*., has reviewed the success of short implants and concluded that they have a survival rate of 81.5%, whereas longer implants have success rate of 95% [30-34].

Studies have shown that most of the short implants failed after 6 to 18 months general during prosthesis loading phase [32]. Several major causes of short implant failures have been reported. first, Less surface area to dissipate occlusal loads. Second, Higher bite forces in posterior regions .Third, Poorer bone density in posterior regions. fourth, Increased crown height which has been reported to be the most detrimental factor, due to increased vertical cantilever [35, 36].

Hence when a high failure rate of short implant was noticed stress was laid upon increasing the bone implant contact to compensate for the decreased length of implant [37].

Any implant with a diameter more than 3.75mm is termed as a wide diameter implant [38]. Studies have proven than for every increase in 1mm in diameter of implant BIC increases by 15 to 20%. Petrie and Williams performed a finite element analysis to determine the effect of length and diameter on stress distribution where they found a there is about 3.5 fold reduction in overall stress when implants with riders diameter were used in comparison to implants with narrow implants [39-41]. Other studies also demonstrated that implants with wider diameter always helps in reducing the overall stress concentration specially at the crestal level, hence concluding that for an effective stress distribution a wider diameter implant is more important than a longer implants [42-44].

Non Threaded implant vs Threaded implant

Cylinder or press fit implants which uses friction for primary stabilization had high success rate initially but fails in the long run, Scortecci *et al*., observed a 50% failure rate during a 10 years followup. Cylindrical design apply maximum amount of shear stress than any other stress like compressive or tensile loading to a reduced BIC as well as increased bone resorption [45].

To overcome the disadvantages of non threaded design, threaded implant body systems were introduced. Due to increased in number of threads, they were thought to apply more of compressive forces then shear stress additionally increased in the surface area for a higher BIC. The increased BIC helps to provide an increased functional surface area, making this design system more efficient.

Functional surface areas actively distribute forces and are independent of theoretical surface area s which comprise of surface roughness and generally play role in increasing in BIC as well as initial stability, But when loads are applied to the implant body Functional surface area i.e thread plays role in stress distribution [46]. Tete *et al*., in 2012 concluded that implant design is a more important factor after loading than implant surface condition after it has been loaded [47].

Thread geometry

Thread on an body of an implant we're designed to increase implant stability by increasing the surface area, along with dissipation of load at bone implant interface. Thread geometry i.e Thread pitch, Thread shape, thread depth plays an important role in these functions [46].

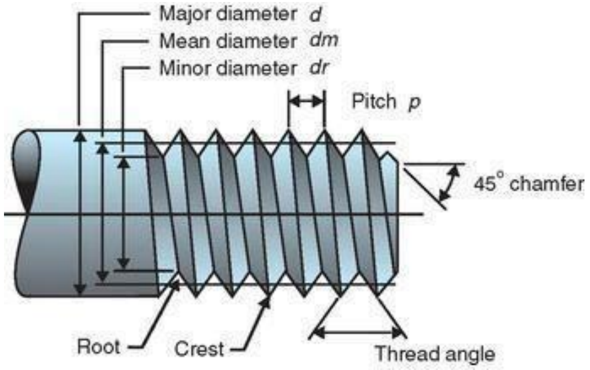

Fig 1: Thread geometry

Thread Pitch is defined as the distance measured parallel between two adjacent threads. Smaller the pitch of an implant thread for a given length greater is the surface area per unit length. Roberts et al conducted a study to determine the effect of thread pitch on BIC and concluded that increasing the number of thread per unit length will result in an increased surface area which further led to decrease in the stress. Hence when ideal implant length cannot be possible, increasing the number of threads can compensate for the decrease in implant length [48, 49].

Ester *et al*., stated that ideal thread pitch distance should be 0.808 mm for optimal stress distribution [50]. Liang *et al*., found that thread pitch can play an important role in protecting dental implant under both axial as well as non axial loading [51].

Thread depth is defined as the distance between the major and minor diameter of the thread. Greater the implant thread depth greater will be the surface area [52]. Sun *et al*., conducted a study to evaluate the effect of the thread depth on the mechanical properties of implant and found that increasing the thread depth of an implant found that, increased the insertion torque required, but did not decrease its compressive strength. Hence these Implant have better implant stability in areas of poor quality bone without Affecting itS mechanical properties [53].

Thread shape: thread shapes in dental implant are of four types v shape, square shape buttress, and reverse buttress shape, V shape threads are also called fixture with an angle of 30 degree. whereas square thread design are called power thread [12]. The primary application of thread design pertains to the loading conditions and may also contribute to the initial healing stage for the direct bone interface. In vivo study conducted by Steigenga *et al*., comparing three different thread shapes with identical implant width, length, thread number, thread depth and surface condition [54], concluded that The v shaped thread design and reverse buttress thread shape design had similar Bone implant contact percent and similar reverse torque values required to remove the implant after initial healing is completed. Out of the three design square thread design present to be the highest BIC percent and a greater reverse torque test value. Therefore thread shapes also an important parameter for implant design in the initial healing phase of osseointegration. In general, dental materials are generally strongest under compressive loads compared to the shear loads or tensile stress. This is applicable generally for ceramics, cements, implant biomaterials, fixation screws and bone. Therefore it is always advisable to apply a compressive force to all these components and shear force should be avoided wherever possible.

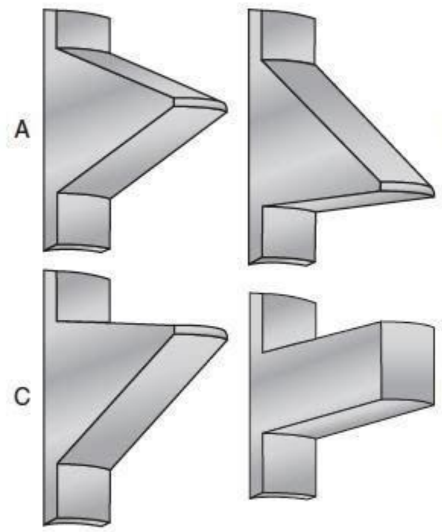

Fig 2: The four most common thread shapes for implant design are V-thread (A), reverse buttress thread (B), buttress thread (C), and square thread (D)

The face angle of the thread design in an implant body can modify the direction of the occlusal load applied on the prosthesis and connection to a completely different direction of the bone interface. V shaped thread has a face angle of 30 degree off the long axis when compared to a square thread design which generally has 90 degree face angle to the long axis of implant [55], because of which all the occlusal load applied on square thread face angel provide compressive forces at the bone interface, but scene changes as thread face angle changes to v shape they apply more of a shear loads at the bone interface. The shear force applied by v thread face ie 30 degree 10 times greater than that of shear force applied by square thread. The shear forces applied per unit length by a reverse buttress thread design is almost similar to a V shape thread design when subjected to an occlusal load. The reduction in shear loading and increasing the compressive load is particularly important in region with bone density of D3 D4, short implant lengths less than 7mm, or in the posterior region were there is higher force magnitudes [56]. Therefore, when a axial load is delivered to an implant the face angle of the implant body thread can modify the occlusal axial load to an angle bone implant load [57]. A power thread (square) may load the bone interface in compression when the axial load is delivered to the implant crown. A finite element studies done by both Kim *et al*., and Chun *et al*., concluded that square thread have lesser stress in both compressive and shear forces and thus are a beneficial shape occlusal loading when compared with other thread design [12].

Apical Region

Apical portion of implants are generally tapered to permit the seating of implant in the prepared osteotomy even before the body engages the side wall of bone. As bone is weaker to torsional forces, to prevent this forces, anti rotational features were added to the apical region in the form of holes or vents. It was thought that bone can be grown within these holes thus increasing the BIC and also resisting torsional load. However, when implants were placed in approximation to sinus floor these holes were seen to have fibrous growth instead of bone thus leadings to implant failure. Therefore, holes or vents were discontinued and flat sides with or without grooves were introduced [12].

CONCLUSION

It is always advisable to place implantS with length of more than 10mm and diameter more than 3.75mm in order to achieve maximum bone implants contact. In poor density bone it is advisable to give more emphasises on implant body surface design ie thread geometry and a rough surface topography in order to achieve greater BIC. In such condition square thread design with a deeper thread and a pitch of 0.808 mm should be preferred to improve the primary stability. Because implants can withstand compressive forces better than tensile or shear stress so designing of an implant is selected in such a way that maximum biting forces should beef compressive nature.

No one implant design is ideal for every presented situation. Hence it is required to select the implant scientifically on the basis of bone quality and quantity, in order to increase the long term success rate.

REFERENCE

1. Branemark, P. I. (1977). Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand. J. Plast. Reconstr. Surg. Suppl.*, *16*, 1-132.
2. Adell, R., Lekholm, U., Rockler, B. R. Ä. N. E. M. A. R. K., & Brånemark, P. I. (1981). A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *International journal of oral surgery*, *10*(6), 387-416.
3. van Steenberghe, D., Lekholm, U., Bolender, C., Folmer, T., Henry, P., Herrmann, I., ... & Åstrand, P. (1990). The Applicability of Osseointegrated Oral Implants in the Rehabilitation of Partial Edentulism: A Prospective Multicenter Study on 558 Fixtures. *International Journal of Oral & Maxillofacial Implants*, *5*(3), 272–281.
4. Buser, D., Weber, H. P., Brägger, U., & Balsiger, C. (1991). Tissue integration of one-stage ITI implants:

3-year results of a longitudinal study with Hollow-Cylinder and Hollow-Screw implants. *International Journal of Oral & Maxillofacial Implants*, *6*(4), 405–412.
5. Adell, R., Eriksson, B., Lekholm, U., Brånemark, P. I., & Jemt, T. (1990). A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *International Journal of Oral & Maxillofacial Implants*, *5*(4), 347–359.
6. Albrektsson, T., Dahl, E., Enbom, L., Engevall, S., Engquist, B., Eriksson, A. R., ... & Åstrand, P. (1988). Osseointegrated oral implants: a Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. *Journal of periodontology*, *59*(5), 287-296.
7. Misch, C. E. (1990). Density of bone: effect on treatment plans, surgical approach, healing, and progressive boen loading. *The International journal of oral implantology: implantologist*, *6*(2), 23-31.
8. Schnitman, P. A., Rubenstein, J. E., Woehrle, P. S., DaSilva, J. D., & Koch, G. G. (1988). Implants for partial edentulism. *The International Journal of Oral Implantology: Implantologist*, *5*(2), 33-35.
9. Albrektsson, T., & Lekholm, U. (1989). Osseointegration: current state of the art. *Dental Clinics of North America*, *33*(4), 537-554.
10. Lekholm, U., & Zarb, G. A. (1985). Tissue Integrated Prostheses. Osseointegration in Clinical Dentistry. Chicago: Quintessence Publishing Co.
11. Baumeister, T., & Avallone, E. A. 1978). Marks' standard handbook of mechanical engineers, ed 8, New York, McGraw-Hill.
12. Misch, C. E., & Bidez, M. W. (1999). A scientific rationale for dental implant design. In Misch, C. E., editor: Contemporary implant dentistry, ed 2, St Louis, Mosby.
13. Hermann, J. S., Cochran, D. L., Hermann, J. S., Buser, D., Schenk, R. K., & Schoolfield, J. D. (2001). Biologic Width around one-and two-piece titanium implants: A histometric evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. *Clinical oral implants research*, *12*(6), 559-571.
14. Hämmerle, C. H., Brägger, U., Bürgin, W., & Lang, N. P. (1996). The effect of subcrestal placement of the polished surface of ITI® implants on marginal soft and hard tissues. *Clinical oral implants research*, *7*(2), 111-119.
15. Weiner, S., Simon, J., Ehrenberg, D. S., Zweig, B., & Ricci, J. L. (2008). The effects of laser microtextured collars upon crestal bone levels of dental implants. *Implant dentistry*, *17*(2), 217-228.
16. Al-Thobity, A. M., Kutkut, A., & Almas, K. (2017). Microthreaded implants and crestal bone loss: A systematic review. *Journal of Oral Implantology*, *43*(2), 157-166.
17. Chun, H. J., Cheong, S. Y., Han, J. H., Heo, S. J., Chung, J. P., Rhyu, I. C., ... & Kim, M. H. (2002). Evaluation of design parameters of osseointegrated dental implants using finite element analysis. *Journal of oral rehabilitation*, *29*(6), 565-574.
18. Lekholm, U. L. F., Gunne, J., Henry, P., Higuchi, K., Lindén, U., Bergström, C., & Van Steenberghe, D. (1999). Survival of the Brånemark implant in partially edentulous jaws: a 10-year prospective multicenter study. *International Journal of Oral and Maxillofacial Implants*, *14*(5), 639-645.
19. Hernigou, P., Queinnec, S., & Flouzat Lachaniette, C. H. (2013). One hundred and fifty years of history of the Morse taper: from Stephen A. Morse in 1864 to complications related to modularity in hip arthroplasty. *International orthopaedics*, *37*(10), 2081-2088.
20. Prithviraj, D. R., Muley, N., & Gupta, V. (2012). The evolution of external and internal implant–abutment connections: A review. *International Dental Research*, *2*(2), 37-42.
21. Chun, H. J., Shin, H. S., Han, C. H., & Lee, S. H. (2006). Influence of implant abutment type on stress distribution in bone under various loading conditions using finite element analysis. *International Journal of Oral & Maxillofacial Implants*, *21*(2), 195-202.
22. Resende, C. C. D., Castro, C. G., Pereira, L. M., Prudente, M. S., Zancopé, K., Davi, L. R., ... & das Neves, F. D. (2015). Influence of the prosthetic index into Morse Taper implants on bacterial microleakage. *Implant dentistry*, *24*(5), 547-551.
23. Caricasulo, R., Malchiodi, L., Ghensi, P., Fantozzi, G., & Cucchi, A. (2018). The influence of implant-abutment connection to peri-implant bone loss: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research*, *20*(4), 653-664.
24. Quaresma, S. E., Cury, P. R., Sendyk, W. R., & Sendyk, C. (2008). A finite element analysis of two different dental implants: stress distribution in the prosthesis, abutment, implant, and supporting bone. *Journal of Oral Implantology*, *34*(1), 1-6.
25. Maeda, Y., Satoh, T., & Sogo, M. (2006). In vitro differences of stress concentrations for internal and external hex implant–abutment connections: a short communication. *Journal of oral rehabilitation*, *33*(1), 75-78.
26. Buser, D., Schenk, R. K., Steinemann, S., Fiorellini, J. P., Fox, C. H., & Stich, H. (1991). Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *Journal of biomedical materials research*, *25*(7), 889-902.
27. Misch, C. E., & Bidez, M. W. (1994). Implant-protected occlusion: a biomechanical rationale. *Compendium (Newtown, Pa.)*, *15*(11), 1330-1332.
28. Misch, C. E. (1999). Short versus long implant concepts—functional surface area, *Dent Today*, 18, 60-65.
29. Misch, C. E. (1999). Short versus long implant concepts—functional surface area, *Oral Health*, 89, 13-21.
30. Neves, F. D., Fones, D., & Bernardes, S. R. (2006). Short implants—an analysis of longitudinal studies, *Int J Oral Maxillofac Implants*, 21, 86-93.
31. Winkler, S., Morris, H. F., & Ochi, S. (2000). Implant survival to 36 months as related to length and diameter, Ann Periodontol, 5, 22–31.
32. Weng, D., Jacobson, Z., Tarnow, D., Hürzeler, M. B., Faehn, O., Sanavi, F., ... & Stach, R. M. (2003). A prospective multicenter clinical trial of 3i machined-

surface implants: results after 6 years of follow-up. *International Journal of Oral & Maxillofacial Implants*, *18*(3), 417-423.

33. Jemt, T., & Lekholm, U. (1995). Implant treatment in edentulous maxillae: a 5-year follow-up report on patients with different degrees of jaw resorption. *International Journal of Oral & Maxillofacial Implants*, *10*(3), 303-311.
34. Naert, I., Koutsikakis, G., Duyck, J., Quirynen, M., Jacobs, R., & Van Steenberghe, D. (2002). Biologic outcome of implant-supported restorations in the treatment of partial edentulism: Part 1: A longitudinal clinical evaluation. *Clinical oral implants research*, *13*(4), 381-389.
35. Misch, C. E. (2005). Short dental implants: a literature review and rationale for use. *Dentistry today*, *24*(8), 64-68.
36. Lum, L. B. (1991). A biomechanical rationale for the use of short implants. *The Journal of oral implantology*, *17*(2), 126-131.
37. Bulaqi, H. A., Mousavi Mashhadi, M., Safari, H., Samandari, M. M., & Geramipanah, F. (2015). Effect of increased crown height on stress distrib-ution in short dental implant components and their surrounding bone:A fi-nite element analysis. *The Journal of Prosthetic Dentistry*, 113(6), 548–557.
38. Al-Johany, S. S., Al Amri, M. D., Alsaeed, S., & Alalola, B. (2016). Dental Implant Length and Diameter: A Proposed Classification Scheme. *Journal of Prosthodontics*, 26(3), 252–260.
39. Petrie, C. S., & Williams, J. L. (2005). Comparative evaluation of implant designs: influence of diameter, length, and taper on strains in the alveolar crest: A three-dimensional finite-element analysis. *Clinical oral implants research*, *16*(4), 486-494.
40. Himmlova, L., Kácovský, A., & Konvičková, S. (2004). Influence of implant length and diameter on stress distribution: a finite element analysis. *The Journal of prosthetic dentistry*, *91*(1), 20-25.
41. Baggi, L., Cappelloni, I., Di Girolamo, M., Maceri, F., & Vairo, G. (2008). The influence of implant diameter and length on stress distribution of osseointegrated implants related to crestal bone geometry: A three-di-mensional finite element analysis. *The Journal of Prosthetic Dentistry*, 100(6), 422–431.
42. Abraham, H. M., Philip, J. M., Jain, A. R., & Venkatakrishnan, C. J. (2016). The effect of implant and abutment diameter on peri-implant bone stress: A three-dimensional finite element analysis. *Journal of Oral Research and Review*, *8*(2), 49-52.
43. Ding, X., Liao, S. H., Zhu, X. H., Zhang, X. H., & Zhang, L. (2009). Effect of diameter and length on stress distribution of the alveolar crest around immediate loading implants. *Clinical implant dentistry and related research*, *11*(4), 279-287.
44. Scortecci, G. M., Bert, M., & Leclercq, P. (2000). Complications, prevention, correc-tion and maintenance. In Scortecci G. M., Misch, C. E., Brenner, K. U, editors: Implant and restorative dentistry, New York, Martin Dunitz.
45. Strong, J. T., Misch, C. E., Bidez, M. W., & Nalluri, P. (1998). Functional surface area: thread-form parameter optimization for implant body design. *Compend Contin Educ Dent*, *19*(3), 4-9.
46. Tetè, S., Zizzari, V., De Carlo, A., Sinjari, B., & Gherlone, E. (2012). Macroscopic and microscopic evaluation of a new implant design supporting immediately loaded full arch rehabilitation. *Annali di stomatologia*, *3*(2), 44-50.
47. Roberts, W. E., Smith, R. K., Zilberman, Y., Mozsary, P. G., & Smith, R. S. (1984). Osseous adaptation to continuous loading of rigid endosseous implants. *American journal of orthodontics*, *86*(2), 95-111.
48. Orsini, E., Giavaresi, G., Trirè, A., Ottani, V., & Salgarello, S. (2012). Dental implant thread pitch and its influence on the osseointegration process: an in vivo comparison study. *International Journal of Oral & Maxillofacial Implants*, *27*(2), 383-392
49. Lan, T. H., Du, J. K., Pan, C. Y., Lee, H. E., & Chung, W. H. (2012). Biomechanical analysis of alveolar bone stress around implants with different thread designs and pitches in the mandibular molar area. *Clinical oral investigations*, *16*(2), 363-369.
50. Misch, C. E. (2006). Wide-diameter implants: surgical, loading, and prosthetic considerations. *Dentistry today*, *25*(8), 66-71.
51. Lee, S. Y., Kim, S. J., An, H. W., Kim, H. S., Ha, D. G., Ryo, K. H., & Park, K. B. (2015). The effect of the thread depth on the mechanical properties of the dental implant. *The journal of advanced prosthodontics*, *7*(2), 115-121.
52. Steigenga, J. T. (2003). The effect of implant thread geometry on strength of osseointegration and the bone implant contact. *Ann Arbor, MI*.
53. Strong, J. T., Misch, C. E., Bidez, M. W., & Nalluri, P. (1998). Functional surface area: thread-form parameter optimization for implant body design. *Compend Contin Educ Dent*, *19*(3), 4-9.
54. Reilly, D. T., & Burstein, A. H. (1975). The elastic and ultimate properties of compact bone tissue. *Journal of biomechanics*, *8*(6), 393-405.
55. Chun, H. J., Cheong, S. Y., Han, J. H., Heo, S. J., Chung, J. P., Rhyu, I. C., ... & Kim, M. H. (2002). Evaluation of design parameters of osseointegrated dental implants using finite element analysis. *Journal of oral rehabilitation*, *29*(6), 565-574.