ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 2, March - 2022, Page No. : 454 - 461

Design failures in implants - A critical review

[1]Dr. Madhura Mangalvedhekar, Reader, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

[2]Dr. Mahantesh Achnur, Reader, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

[3]Dr. Siddharam Patil, Reader, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

[4]Dr. Supriya Bijjargi, Reader, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

[5]Dr. Mohammad Nabeel Kalburgi, Senior Lecturer, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

Corresponding Author: Dr. Madhura Mangalvedhekar, Reader, Department of Prosthodontics and Crown and Bridge, P.M.N.M. Dental College and Hospital, Bagalkot, Karnataka.

Citation of this Article: Dr. Madhura Mangalvedhekar, Dr. Mahantesh Achnur, Dr. Siddharam Patil, Dr. Supriya Bijjargi, Dr. Mohammad Nabeel Kalburgi, “Design failures in implants - A critical review”, IJDSIR- March - 2022, Vol. – 5, Issue - 2, P. No. 454 - 461.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Statement of problem: There are various implant designs and implant systems available today. The implant designs have been evolved from the simple blade vent implant to and more sophisticated tapered and thread designs. But the clinician is always posed with the perplexing problem as to which design to use in a particular patient for optimum health, function and aesthetics.

Purpose: The purpose of this article is to review the various designs of implants and their failures and complications.

Conclusion: Various concepts and philosophies have been evolved for best implant design in regards to length, diameter, material etc. The most contemporary design is the threaded root-form implant with micro threads and porous surface with various surface characterizations to improve bio integration. The length and diameter also play a crucial role in long-term implant stability. The thumb rule is to place one implant

per missing tooth for better stress distribution and occlusal stability.

Keywords: Design, Threaded implants, non-threaded implants, surface characterization, Hydroxyapatite-coated implants.

Introduction

Implant dentistry is both art and science, the aim of which is the bio-artificial restoration of the lost dental organ so that it will adequately fulfill the aesthetic, phonetic and functional requirements of the patient. Multidisciplinary research and clinical trials have played an essential role in the development of state-of-the-art implant systems to satisfy both professional requirements and the patient's need for safe and effective therapy. However, an implant prosthetic reconstruction does not offer miracles. Complications and failures are inevitable. The dentist has to be able to analyze a given clinical situation and evaluate its complexity.

Subsequent analysis of failures will lead to better understanding of the parameters that permit a high overall treatment success rate with health, function and aesthetics.

Implant design refers to the three-dimensional structure of the implant in regards to the form, shape configuration, geometry, length and diameter, surface macro-structure and micro irregularities.[1] A favorable implant design may compensate for the risk of poor bone densities, excessive occlusal load and inadequate width and height of bone resulting in a compromised implant position, number and size.[1] Criteria for implant success includes that the implant should be immobile. There should be no peri-implant radiolucency in the radiograph; the vertical bone loss should be less than 2mm. There should be no pain, infections, neuropathies and paresthesia.[1]

Now-a-days, various implants are available with number of designs; cylindrical, screw-shaped, threaded, non-threaded, smooth, and a combination of all these characters. In this article, we will be discussing the failures of the designs of each design and its evolution into a better design.

Implant designs

Shape (Taper)

Blade vent implants were the first implants introduced to dentistry in 1960s by Linkow. Excessive bone drilling was required for their insertion, leading to lot of bone loss and inflammatory reaction. Also the large vents encouraged fibrous growth and gradually total fibrous encapsulation of the blades, ultimately leading to mobility of the implant and thus failure.[1]

Dr. Per-Ingvar Brane mark, an orthopaedic surgeon from University of Goteburg, Sweden, revolutionized the realm of implant dentistry by introducing the concept of osseointegration. He developed and tested a type of dental implant utilizing pure titanium screws, which he termed fixtures.

The cylindrical or press fit implants were introduced in early 1970s. Longitudinal studies conducted by Scortecci et al showed crestal bone loss and ultimately implant failure after 5 years with this design.[2] The bone loss may be attributed to inadequate primary stability because of decreased bone-implant contact leading to micro movements of the implant within the bone. In addition to this, the harmful shear loads after restoration of the prosthesis will lead to failure of the implant. Alberktsson et al[3] studied cylindrical implants and found that there is continuing bone saucerization of 1mm for the first year, 0.5mm annually and thereafter increasing rate of resorption up to 5 years.

For improving stability and to reduce failure rate, screw-shaped implants were developed. They have adequate primary stability due to the nature of the bone-implant interface. But due to the screw shape (the diameter at the apex is smaller compared to the rest of the body), under shear occlusal loads, bone loss is seen at the crest level eventually leading to exposure of threads and finally failure of the implant. This will lead to accumulation of plaque and bacteria leading to continuous inflammatory process with further bone resorption, finally causing mobility of the implant. Also due to the sudden taper in the screw-shaped implants, a slip plane is developed which leads to movements of implant within bone. To avoid this, double and triple tapered implants were developed. They have high initial stability and triple tapered implants have better results than double-tapered.

Threads

The non-threaded implants have less of bonding to the bone and tend to slip. A slip plane is created within the bone and titanium leading to mobility and ultimately failure of the implant (Fig. 1). The smooth crest module placed below crestal bone will lead to marginal bone loss from extension of biologic width. This will increase the peri-implant sulcus depth, leading to bacterial accumulation and thus inflammatory process leading to further bone resorption.[1] Ham merle CH et al[4] studied the effect of sub crestal placement of polished surface of ITI implants on marginal soft tissues and found out that there is marginal bone loss from extension of biologic width. Hermann et al[5] studied the effect of smooth and rough surfaced implants on the loss of bone and reported that, smooth surfaced implants lost 1.5mm bone in a month while rough surfaced implants maintained the bone for 6 months. Bolind et al[6] compared the threaded and non-threaded implants in 117 patients and reported that greater bone implant contact was found with threaded implants while greater marginal loss was observed around smooth implants.

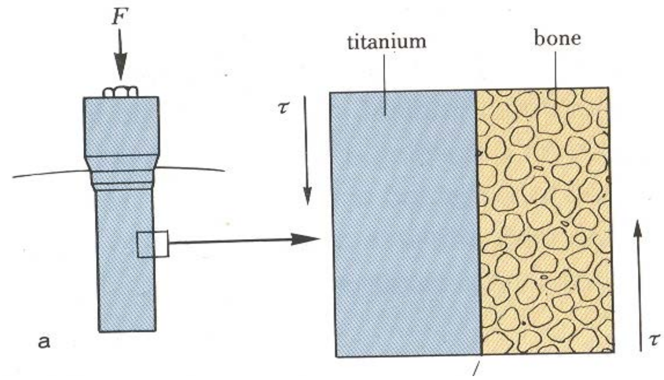

Fig. 1: Non-threaded implant showing slip-plane.

There are basic 3 thread designs: standard V-shaped, square- shaped and buttress shape.[1] (Fig.2) The threads help in better bonding of the implant to bone and prevent movements of the implant within the bone. The threads are rounded to reduce stress concentration (Fig.3). It is noted that V- shaped thread has more shear forces during initial loading and also due to less surface area, there is lack of initial stability. Steigenga et al[7] compared three thread shapes with identical implant length, width, depth and surface condition and reported that the square thread design had a higher bone-implant contact. Previously, only single threads were incorporated in the body of the implant, called macro-threads. Recently, micro-threaded implants have been evolved which have better initial stability due to ingrowth of bone in the grooves. But it should be kept in mind that these implants are difficult to place in the dense cortical bone and hence, have to be screw-tapped.

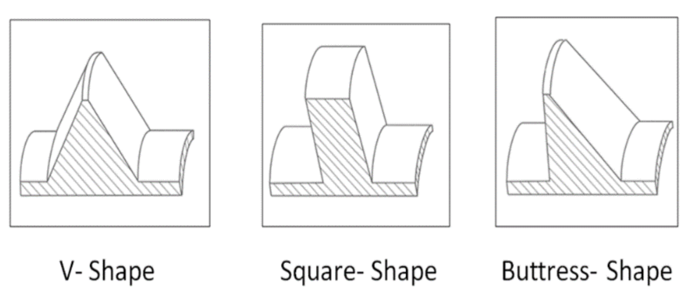

Fig. 2: Thread designs: V-shaped, Square-shaped and Buttress-shaped.

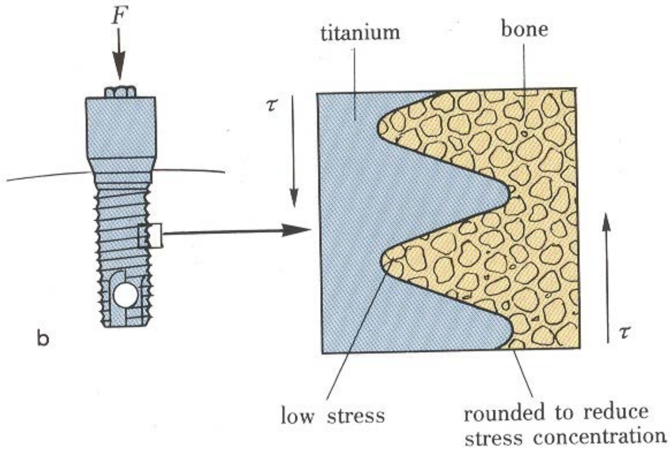

Fig. 3: Rounded threads to reduce stress concentration

Apical design

Initially, the apical design of implant was tapered with circular cross-section. This did not resist torsion forces when abutment screws are tightened leading to mobility of the implant after a period. To avoid this, a vent was incorporated as an anti-rotational feature in the apical body. But it was observed that this vent got filled with mucous when placed through sinus floor or exposed through a cortical plate. This would lead to retrograde contamination. Also, it used to get filled with fibrous tissue leading to decrease in bone contact, ultimately causing implant failure. To avoid all these complications, the apical design evolved through time and now the best apical geometry is tapered geometry with flat sides and grooves on the sides.[1]

Length

High failure rate is noted in short implants after prosthetic loading.[1] This may be attributed to low ratio of implant to bone contact leading to osseointegration failure. Also posterior short implants have high failure rate due to higher bite forces, less bone density in the posterior region and due to increased crown height.[12] Weng et al[9] conducted a study for 6 years and reported that short implants in posterior maxilla had highest early loading failure. Misch[1] reviewed the literature between 1981 and 2004 and found an overall 18% failure rate with shorter implants. Goodacre et al[10], das Neves et al[11] and Tawil et al[12] conducted studies on survival and complication rates of short implants and it was summarized that failure rates of short implants were 10% compared with 3% failure rate of longer implants. Thus longer implants with larger surface area and better bone-implant contact are advocated. But before the placement of any long implant, the available bone height, the position of nerves and the forces that will be exerted should be properly evaluated. It should be noted that excessive long implants do not transfer stress to the apical region.[13]

Diameter

Smaller diameter implants have less surface area and they cause failure in cases of increased crown length, increased masticatory dynamics, in molar regions and in cantilever designs. Winkler et al[14] studied the influence of implant diameter on implant survival and reported that 3mm diameter implants had survival rate of 90.7%, while 4mm diameter implants had survival rate of 95%. Similar study was conducted by Krennmair et al[15] with 5.5mm diameter implant and survival rate of 98.3% was reported. But wider diameter implants have their own limitations and complications. As the crestal bone has to be drilled excessively, there is trauma and healing period is increased. Due to the wide diameter, these implants cannot be used in cases with thin labial cortical plate in the anterior region. The available bone has to be evaluated before placement of the implant to avoid encroachment of the PDL space of the adjacent tooth or the bone surrounding the adjacent implant. Initially external hex design was used, but this led to screw loosening during torquing, hence now internal hex implants are used with optimum results.

Material

The surface characteristics of the implants were improvised over time for better bone-implant interface. First introduced implant material was commercially pure titanium. It is a metal that presents low weight, high strength/weight ratio, low modulus of elasticity, excellent corrosion resistance, excellent biocompatibility and easy shaping and finishing.[16] It was widely used with optimum results. But it lacked hardness and had excess thermal conductivity. So, aluminum and vanadium were added to produce titanium, 6-aluminium, 4-vanadium alloy. This has increased hardness, decreased thermal conductivity, improved elastic modulus and decreased specific gravity.[16] This is the material still widely used in implant dentistry.

Surface

The turned surfaced implants were used for a short while, but were a failure due to less stabilization owing to less surface area.[17] Aluminum oxide and titanium dioxide were used to sandblast the titanium surface for improvement of adhesion to bone. Piatelli et al[18] and Wennerberg et al[19] conducted studies to analyze bone response with turned and sandblasted surfaces and concluded that with Al_2O_3 sandblasting, bone-implant contact was higher (47%) compared to turned surfaces (23%). Titanium plasma-sprayed surfaces were introduced as it accelerated and enhanced bone growth into pores, thus giving good implant stabilization due to better bonding with bone. But detachment of titanium was noted in plasma-sprayed surface when implant was inserted with friction. Franchi et al[20] investigated the detachment of particles around plasma sprayed implants and found titanium debris around these implants after 14 days. Acid-etched surfaces were proposed to modify the implant surface without leaving the residues found after the sandblasting, to avoid non-uniform treatment of the surface and to control loss of metallic substances. Sulfuric, nitric and hydrochloric acid or a combination are used to acid etch implant surfaces. Degidi et al[12] presented the histologic analysis of two dual acid-etched implants (HCl and H_2SO_4) and it was noted that the mean bone implant contact (BIC) was 61.3% with no gaps or fibrous tissues present at the interface. Cell cytotoxicity was noted in acid-etched surfaces due to presence of acid and osseointegration was found to be delayed. Anodized surfaces were developed to create micropores without depositing grit particles. There is lack of cytotoxicity and more of cell attachment and proliferation.[22] Ivan Hoff et al[23] compared the BIC with turned and oxidized surfaces and found that after 6 months, BIC with oxidized surfaces was higher (34%) than turned surface (13%). Recent modification is the hydroxyapatite (HA) coating over titanium surfaces. The advantages of HA coating over turned, sandblasted, plasma-sprayed or oxidized surfaces are that faster bone healing is seen in HA coated surfaces, there is increased gap healing between bone and HA, thus stronger interface is formed and better stabilization is seen. Also, due to HA coating there are chances of less corrosion of metal.[102] In a study conducted by Uehara T et al,[24] it was found that HA coated implants had high survival rates and BIC was also higher (97.4%). Also it was noted that the connection between HA coating and the metal was uniformly tight and constant (30-50µm). Schwartz-Arad et al[25] evaluated HA coated implants and titanium implants for 12 years and concluded that HA coated implants have high survival rates (93.2%) compared to titanium implants (89%). But HA coating has its complications and disadvantages.[1] Increased flaking, cracking or scaling of the HA coating is seen during insertion of implant. Due to the roughness, there is increased plaque retention, leading to bacterial accumulation and inflammatory process, resulting in increased healing time. If the inflammation continues, there is continuous bone loss, leading to implant failure. Piatelli et al[26] reported localized chronic suppurative bone infection as a sequel of peri-implantitis in a HA-coated implant. The decision to use a hydroxyapatite coating is mainly based on the bone density. Type 1 and type 2 bone have greatest strength and thus increased risk of material flaking during insertion. Type 4 bone has proven to be optimal for HA-coated implants. Zirconia implant[27,28] is the improvised version of titanium implants. They are biocompatible, bioinert, radiopaque and have high resistance to corrosion, flexion and fracture. Bone response to zirconia implants was evaluated by Senner by L et al[29] and it was found that the BIC was higher (68.4%) and also there was absence of epithelial down growth, foreign bone reaction, gaps or fibrous tissue between bone and implant. Studies are still being conducted on zirconia implants in regards to their success and improvisation.

Conclusion

The systematic understanding of various factors related to implant design such as the implant length, diameter, thread geometry, apical design and configuration as well as the site of implant and position and number of implant helps us to arrive at the reasons for success as well as failure of implants. A careful evaluation of the available implant designs and their application in specific sites ensure implant success. It is important that the implant engage adequate height and width of the maximum available cortical bone to ensure good primary stability. Longer implants have good stability owing to better bone-implant contact. However, short implants have also shown success particularly in case of maxillary posterior region where available bone is compromised. The most contemporary threaded and micro-threaded implants with triple tapered root form geometry are preferred for good primary stability and successful osseointegration. The surface characterization of the implant is important to assure better bone-implant contact. Surface treated titanium implants have proved to acquire better bio integration.

References

1. Misch CE: Contemporary Implant Dentistry, ed 3, St. Louis 2008. Mosby.
2. Scortecci GM, Bert M, Lecclercq P: Implant and Restorative Dentistry, New York 2000. Martin Dunitz.
3. Albrektsson T, Dahl F, Enbom L: A multicenter report on osseointegrated oral implants. J Prosthet Dent 1993; 60:75-84.
4. Hammerle CH, Bragger U, Burgin W et al: The effect of subcrestal placement of the polished surface ITI implants on marginal soft and hard tissues. Clin Oral Implants Res 1996; 7:111-119.
5. Hermann JS, Cochran DL, Nummikoski PV et al: Crestal bone changes around titanium implants: a radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. J Periodontol1997; 68:1117-1130.
6. Bolind PK, Johansson CB, Becker W et al: A descriptive study on retrieved non-threaded and threaded implant designs. Clin Oral Implants Res 2005; 18:447-455.
7. Steigenga J, Al-Shammari KF, Misch CE: Effects of implant thread geometry on percentage of osseointegration and resistance to reverse torque in the tibia of rabbits. J Periodontol 2004; 75:1233-1241.
8. Misch CE: Short dental implants: a literature review and rationale for use. Dent Todat 2005; 24:64-68.
9. Weng D, Jacobsson Z, Tarnow D et al: A prospective multicenter clinical trial of 3i machined-surface implants: results after 6 years of follow-up. Int J

Oral Maxillofac Implants 2003; 18:417-423.

10. Goodacre CJ, Bernal G, Runcharassaeng K et al: Clinical complications with implants and implant prostheses. J Prosthet Dent 2003; 90:121-132.

11. Das Neves FD, Fones D, Bernardes SR et al: Short implant – an analysis of longitudinal studies. Int J Oral Maxillofac Implants 2006; 21:86-93.

12. Tawil G, Aboujaoude, Yaunan R: Influence of prosthetic parameters on survival and complication rates of short implants. Int J Oral Maxillofac Implants 2006; 21:275-282.

13. Borchers I, Reidhart P: Three-dimensional stress distribution around dental implants at different stages of interface development. J Dent Res 1994; 62:155-159.

14. Winkler S, Morris HF, Ochis: Implant survival to 36 months as related to length and diameter. Ann Periodontol 2000; 5:22-31.

15. Krenmair G, Walden Berger O: Clinical analysis of wide diameter Frialit 2 implants. Int J Oral maxillofac Implants 2004; 19:710-715.

16. Lautenschlager EP, Monaghan P: Titanium and titanium alloys as dental materials. Int Dent J 1993; 43:245-253.

17. Johansson CB, han CH, Wennerberg A et al: A quantitative comparison of machined commercially pure titanium and titanium-aluminium-vanadium implants in rabbit bone. Int J Oral maxillofac implants 1998; 13:315-321.

18. Piattelli A, Manzon L, Scarano A et al: Histologic and histomorphometric analysis of the bone response to machined and sandblasted titanium implants: an experimental study in rabbits. Int J Oral Maxillofac implants 1998; 13:805-810.

19. Wennerberg A, Hallgren C, Johansson C et al: A histomorphometric evaluation of screw-shaped implants each prepared with two surface roughness. Clin Oral Implants Res 1998; 9:11-19.

20. Franchi M, Bacchelli B, Martini D et al: Early detachment of titanium particles from various different surfaces of end osseous dental implants. Biomaterials 2004; 24:2239-2246.

21. Degidi m, Petrone G, Iezzi G et al: Bone contact around acid-etched implants: a histological and histomorphometrically evaluation of two human-retrieved implants. J Oral Implantol 2003; 29:13-18.

22. Zhu X, Chen J, Scheideler L et al: Effects of topography and composition of titanium surface oxides on osteoblast responses. Biomaterials 2003: 66:520-525.

23. Ivanoff CJ, Widmark G, Johansson C et al: Histologic evaluation of bone response to oxidises and turned titanium micro-implants in human jaw bone. Int J Oral Maxillofac implants 2003; 18:341-348.

24. Uehara t, Takaoka K, Ita K: Histologic evidence of osseointegration in human retrieved fractures hydroxyapatite-coated screw-type implants: a case report. Clin Oral Implants Res 2004; 15 540-545.

25. Schwartz –Arad D, mardinger O, Levin L et al; marginal bone loss pattern around hydroxyapatite-coated versus commercially pure titanium implants up to 12 years of follow up. Int J Oral maxillofac Implants 2005; 20:238-244.

26. Piattelli A, Cosci F, Scarano a et al: Localized chronic suppurative bone infection as a sequel of peri-implantitis in hydroxyapatite-coated dental implant. Biomaterials 1995; 16:917-920.

27. Ichikawa Y, agakawa Y, Nikai H et al: tissue compatibility and stability of new zirconia ceramic in vivo. J Prosthet Dent 1992; 68:322-326.

28. Agakawa Y, Ichikawa Y, Nikai H et al: Interface histology of unloaded and early loaded partially stabilized zirconia end osseous implant in initial bone healing. J Prosthet Dent 1993; 69:599-604.

29. Sennerby L, Dasmah A, Larsson B et al: bone tissue response to surface modified zirconia implants: a histomorphometric and removal torque study in the rabbit. Clin Implant Dent 2005; 7:13-20.