ECRONICON
OPEN ACCESS

EC DENTAL SCIENCE
Review Article

Effect of Surface Design and Morphology on Primary Stability of Dental Implant: A Systematic Review

Maj Amit Bhandari[1] and Neha Vats[2]*

Institute of Nuclear Medicine and Allied Sciences, Delhi, India

***Corresponding Author**: Maj Amit Bhnadari, Institute of Nuclear Medicine and Allied Sciences, Delhi, India.

Received: January 04, 2019; **Publiahed:** February 20, 2019

Abstract

Introduction: Primary stability of implant to the underlying bone is the prime requisite for success of implant. Design and surface characteristics of implant plays an important role in the stability of implant. The present article reviews the available literature on influence of surface characteristics and design of implant on primary stability of implant. Primary stability in most of the studies has been assessed by Resonance Frequency Analysis and Insertion Torque Test. Finite Element Analysis has been used to analyse and understand the thread geometry and profile of implant. Surface has been evaluated by Scanning Electron Microscopy, Profilometry, EDS, XRD.

Objective: The objective of the present study was to review the influence of macro and micro design features of implant over achieving primary stability of dental implant. The purpose is to examine macro design features like thread geometry, thread pitch, helix angle, thread depth and thread width as well as implant crestal module and micro design features like surface morphology and surface treatment and their overall effect on success of implant.

Sources: A literature search was conducted using MEDLINE from 1991, till May 2018. Studies used for review were identified from simulated laboratory models, animal, to human related to this topic using the keywords: Primary Stability, Initial stability, Immediate loading, Implant surface roughness, Osseo integration.

Result: The result showed that implants in good bone quality, tapered, long implants with wide implant diameter and more threads show good primary stability. Micro design features suggest that surface treatment with Calcium deposition through sandblasting provided good results to some authors when loaded immediately. Nanocoatings on implants are being studied for improvement in surface topography and osseointegration.

Keywords: *Primary Stability; Initial Stability; Immediate Loading; Implant Surface Roughness; Osseo Integration*

Introduction

Dental implants are one of the most promising devices used currently for replacement of missing teeth. They have revolutionized oral rehabilitation for managing partially and fully edentulous patients, achieving success rates beyond 90% in long term [1]. Osseo integration is the key for success of implant. Initial cortical is a general recommendation and is very critical for obtaining good Osseo integration and designing of implant plays an important role in providing a "well- seated" implant [2].

Poor primary stability of implant results in implant failure; other related causes include inflammation, bone loss, biomechanical overloading and osteonecrosis [3]. Primary stability influences the secondary stability and gradually the overall stability of the implant. There are four main components that help to achieve primary stability: Implant design, surface of implant, bone quality of the recipient site and the surgical procedure employed for placement of implant [4]. Amongst these, implant design has been studied and associated often with shorter time for surgical procedure and even quick healing rate.

Design features of implant include: Macro design and microdesign features. Macrodesign features include thread pitch, thread geometry, thread depth and width, thread design and implant crestal module while microdesign essentially regards surface morphology and coatings [1].

Macro design features focuses on relationship between osseointegration and mechanical features of implant design engineering and helps to understand which implant to select depending on different clinical conditions.

Micro design features include the study of biological aspect of implant design and focuses on host response pattern and implant survival. It influences cell behaviour on the surface such as adhesion, proliferation and differentiation of cells as well as the mineralization of the extracellular matrix at the implant surfaces [5].

Techniques like blasting, acid-etching, porous sintering, plasma spraying and hydroxyapatite have been used to improve osseointegration. Nanocoating of Titanium implant surface with organic molecules has been used to modify surface properties like hydrophilicity, biochemical bonding capacity and roughness. Still this relation of design of implant and stability remains unclear.

Experimental studies on synthetic bone models have investigated the association between implant surface roughness and degree of attained primary stability. The study showed that the degree of achieved primary stability was significantly higher in etched surfaces compared with machined implant surfaces [6]. A higher surface roughness of etched surface implants has also been associated with increased osteogenic response compared with smooth surface implants [7,8]. However, in one of the study, Balshee., *et al.* reported no difference in survival rates of smooth and rough surfaced dental implants [9].

With the present understanding of subject, this literature review was done to compare different design parameters, surface topography and hydrophilicity of titanium implants after different treatment procedures and their influence on primary stability of implants.

Methods

Objective/Research Question

The objective of the present literature review was to evaluate the influence of surface design of dental implants in achieving initial primary stability of implant.

Eligibility criteria

The following eligibility criteria were imposed:-

1. Pub med articles were evaluated
2. Articles published only in English language
3. Clinical studies and Experimental studies were included
4. Studies involving humans, animals, and *in vivo* were included.

Search strategy

MEDLINE-Pub med databases of National Library of Medicine, Bethesda, Maryland was searched from 1991-May, 2018 using following key words: "Immediate loading", Initial stability", "Primary stability", "Surface roughness", "Osseo integration".

The initial search yielded 665 articles. On scrutiny of titles and abstracts with relevance to implant design and surface, the search resulted into 35 articles. This was followed by hand search and discussion after which authors selected seventeen articles that fulfilled the eligibility criteria. These included clinical trials, experimental studies and review articles.

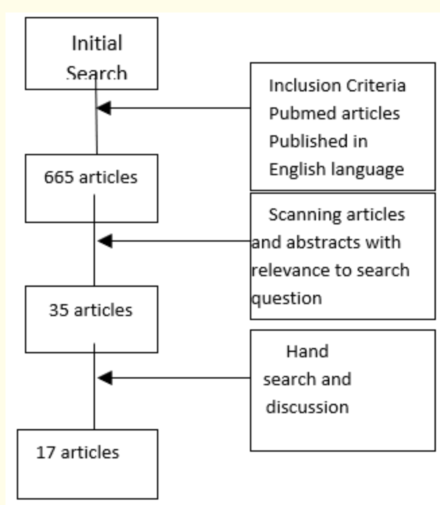

Figure 1: *Schematic representation of methiod used for search strategy*

Result

The studies included in this review were either performed at universities or at well-equipped health centres. The clinical studies that were included have used Resonance frequency analysis and Insertion torque test to record the primary stability. The surface of the implant was studied by Scanning Electron Microscopy, Profilometer, Finite element analysis, EDX and few have also included Atomic Electron Microscopy.

The result showed that implants in good bone quality, tapered, long implants with wide implant diameter and more threads show good primary stability. Micro design features suggest that surface treatment with Calcium deposition through sandblasting provided good results to some authors when loaded immediately. Nanocoatings on implants are being studied for improvement in surface topography and osseointegration.

Discussion

Primary stability at the time of implant placement has been recognized as an important prerequisite for the achievement of Osseo integration. The establishment and maintenance of direct contact at bone-implant interface are requirements for long term implant success [11,11]. Implant design and surface characteristics both are important aspects for primary stability of implant.

Implant design

Thread design

Thread design includes thread shapes. Various thread shapes are designed for effective force insertion and transmission. Thread shape is determined by the thickness and thread face angle. Various shapes available include; V-shape, square shape, buttress and reverse buttress shape [12]. Studies using Finite Element Analysis have shown how thread profile may affect stress concentration and distribution. Out of the different thread designs V-shape and broader square shape generated less stress compared with the thin and narrower square thread in cancellous bone [13]. Likewise in one study, Chang., *et al.* studied different thread designs and their influence on surrounding bone under immediate loading of 300 N axial loading. They found that square thread profile had more favourable micromotion values than rest of the thread shapes [14]. Supporting this is a study by Chun., *et al.* suggesting superiority of square threads because of its maximum stress distribution [15]. Arnhart., *et al.* performed multicentre clinical trials using variable thread tapered implant and suggested that it can be used as a safe and effective treatment modality [16].

Study by	Method	Implants	Load	Conclusion
Chang., *et al*. (2012)	FEA	Implants with Acme thread, buttress thread, square thread, standard V-thread	300 N axial loading	Square thread profile might provide best primary stability under immediate loading
Geng., *et al*. (2002)	FEA	Implants with V-thread, thin thread, thin square thread, thick square thread	Oblique and vertical	1. V-shape and broader square shape generated less stress compared with the thin and narrower square. 2. Thread configuration has effect on stress distribution in trabecular bone only
Chun., *et al*. (2002)	FEA	Plateau type, Plateau with small curvature, triangular, square, square with small radius	100 N axial and 15°	1. Plateau shape had maximum effective stress 2. Square thread filleted with small radius had maximum stress distribution
Arnhart., *et al*. (2012)	Humans 177 patients	Variable thread implants: NIC (Noble active Internal Connection), NAE (Noble Active external Connection), Standard tapered-NR (Noble Replace)	Immediate loading	Variable thread tapered implants showed successful clinical results under immediate loading

Table 1: *List of studies evaluating thread design pattenrs of dental implants.*

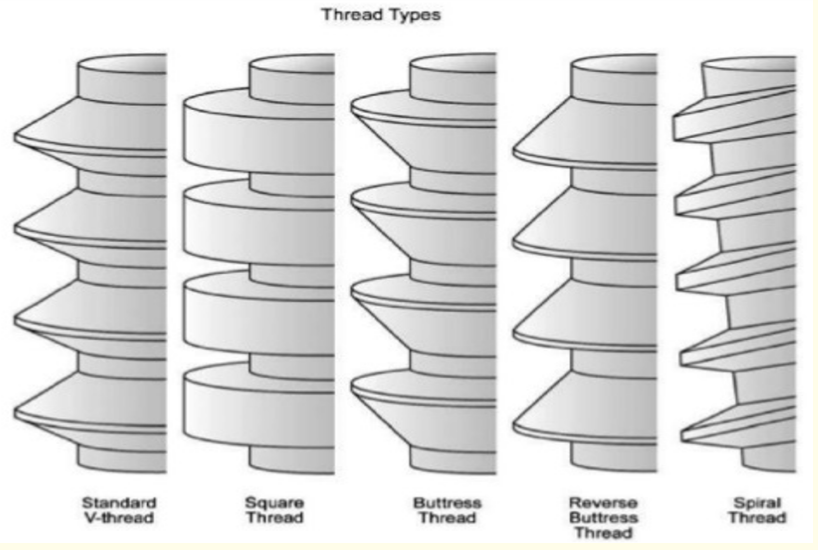

Figure 2: *Different thread designs of implant.*
Source by Hung WY et al.

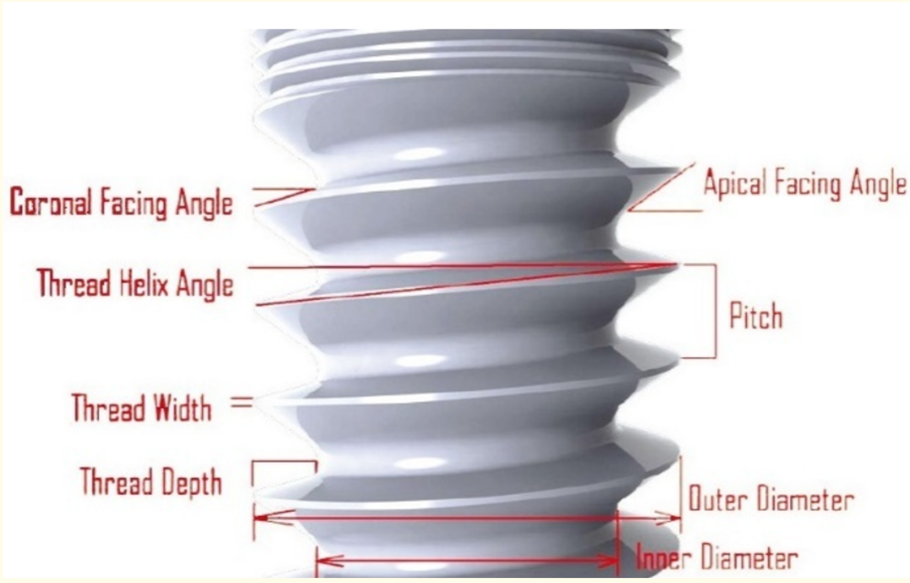

Figure 3: *Image showing different macro design features.*
Source by Abuhussein et al.

Thread pitch

Thread pitch refers to the distance from the centre of the thread to the centre of the next thread, measured parallel to axis of screw and can be calculated by diving unit lengths with by number of threads [17]. It has an inverse relation with the number of threads per unit area. It is different from Lead which is distance from centre of thread to the centre of same thread after one turn or more accurately the distance that screw would advance in axial direction if turned one complete revolution [18]. Now for single-threaded implants lead is equal to pitch but as threads increase to double or triple, the lead increases by one. Now the speed with which implant is inserted in bone depends upon distance implant moves in one turn lead plays an important role; so with double threads insertion would be twice and in triple threaded it would be three times more as compared to single threaded implant as studied by Steigenga., *et al.* [19], Chung., *et al*. and Motoyoshi., et al. suggested that as screw pitch decreases and implant length increases effective stress decreases [20,21]. Here, Chung., *et al.* also suggested that pitch distance of 0.5 mm had less crestal bone loss. Ma., *et al*. suggested that 0.8 mm pitch had stronger resistance that 1.6 and 2.4 mm pitch [22].

Study by	Method	Implants	Load	Conclusion
Ma., *et al*. (2007)	FEA	Implant with thread pitches of 0.8, 1.6 and 2.4 mm	Vertical and horizontal loading	0.8 mm was more resistant to vertical loading
Chung., *et al*. (2008)	Beagle dogs	Branemark with 0.6mm pitch, machined with 0.5mm pitch, thermally oxidized with 0.5 mm pitch	6 - 12 months of loading	1. Branemark 0.6mm pitch has more crestal bone loss. 2. Thermally oxidized pitch showed highest percentage of BIC.
Chun., *et al.* (2002)	FEA	Plateau type, Plateau with small curvature, triangular, square, square with small radius	100 N axial and 15°	Direct relation of stress and pitch; as screw pitch decreases effective stress decreases
Motoyoshi., *et al.* (2005)	FEA	Mini implants with thread pitches from 0.5 - 1.5 mm	Traction forces of 2N at 45° to bone surface	When the abutments are connected low pitch implants have higher stress distribution

Table 2: *List of studies evaluating thread pitch pattern of dental implants.*

Thread depth and width

Thread depth is defined as the distance from the tip of the thread to the body of implant and thread width is defined as the distance in the same axial plane between the coronal most and the apical most part at the tip of single thread. Misch., *et al.* have stated that ' the deeper the threads, the wider the surface area of implant'; greater thread depth may be an advantage in areas of softer bone and higher occlusal force because of higher functional surface area in contact with bone [23]. With a 3-Dimensional FEA model Ao., *et al*. evaluated the maximum Von Mises stress in implants with various thread depths and widths under immediate loading and revealed that thread depth affects the stress distribution more significantly than thread width [24]. In a similar study Kong., *et al.* revealed that optimal thread height ranged from 0.34 - 0.5 mm and thread width between 0.18 - 0.30 mm with thread height being more sensitive than thread width [25].

Study by	Method	Implants	Load	Conclusion
Ao., *et al.* (2012)	FEA	Cylindrical implants with height of 0.2 - 0.6 mm and width of 0.1 - 0.4 mm	100 N axial load 30 N 45°buccolingual load	Thread with depth of 0.44 mm and width of 0.19 - 0.23 mm showed the most favourable results
Kong., *et al.* (2006)	FEA	V-shaped threaded implants with thread height of 0.2 - 0.6 mm and thread width of 0.1 - 0.4 mm	100 N and 50 N of force axial (0° angle and 45° angle)	Optimal height: 0.34 - 0.5 mm optimal width: 0.18 - 0.30 mm

Table 3: *List of studies evaluating thread depth and width of implants.*

Crestal module

The crestal module is the neck portion of the implant. This is an important area as this area is where the implant meets the soft tissue and there is a change from sterile endosteal environment to an open oral cavity. In addition, this area represents thick cortical bone where maximum occlusal stresses are concentrated. Earlier this portion use to remain as smooth portion to prevent plaque accumulation as it used to remain expose and above crestal plate. However recently microthreads in crestal portion have been introduced to maintain marginal bone and soft tissues around implant. According to a study by Schrotenboer., *et al.* in 2008, microthreaded implants increase bone stress at the crestal portion [26]. Lee., *et al.* in 2007 and Amid., *et al.* in 2013 concluded that addition of retentive elements like microthreads effect in preventing marginal bone loss against loading [27,28]. All of these studies suggest that like other design features; microthreads play an important role in preventing marginal bone loss.

Study by	Method	Implants	Load	Conclusion
Schrotenboer., *et al.* (2008)	FEA	Implants with microthreaded crestal module, smooth neck, and platform switching	100 N at 90° vertical and 15° oblique angle, in occlusion for 10 months	Maximum stress values in crestal bone
Lee., *et al.* (2007)	Human patients (17)	Implants with and without microthreaded crestal module	In occlusion, followed for 3 years	Marginal bone loss was lower in microthreaded implants
Amid., *et al.* (2013)	FEA	Implants with and without microthreaded crestal module	100 N vertical load	Microthreads at implant neck reduces stresses in surrounding bone

Table 4: *List of studies showing efffect of crestal modules in stability of dental implants.*

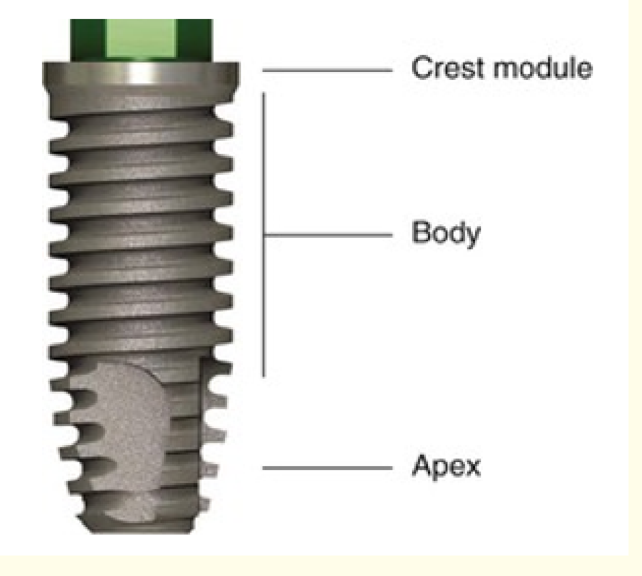

Figure 4: *Image showing the crestal module of dental implant.*
Source by Torroella Saura G et al.

Figure 4: *Image on left is cylindrical implant right is tapered implant.*
Source by Yenumula JB

Other important aspect in implant macro design include implant design. According to Lemons 1993, tapered implants produce more compressive force than cylindrical implant as the latter have more Shear forces and hence higher failure rates [29]. However according to another study by Janine., *et al.* tapered and cylindrical implants showed no significant difference in insertion torque outcome [30]. So it is still debatable question as both show similar biological behaviour during healing phase and it's merely the bone site that can influence insertion torque and primary stability.

Implant surface treatments

Surface modification influences the primary stability of dental implants as it provides a chemical and micromorphological environment that promotes osseointegration. It can be done by adding a layer of hydroxyapatite or tricalcium phosphate onto the surface by plasma spraying or can be ablative whereby the substrate material is removed from the implant surface resulting in creation of roughness over the implant surface. This chemical and surface treatment of titanium during manufacturing influences interaction with the biological cells.

Modifications have been done to improve the biological surface favouring a good bone to implant contact. Wilmowsky., *et al.* found the key factor in implant osseointegration as surface roughness effecting increased osteoblastic activity at 1 to 100 μm [31]. Butz., *et al.* reported that the implant surface roughness affects the biomechanical quality of Osseo integrated bone in that the bone integrated to the rough-surfaced implants is harder and stiffer compared with bone integrated to machined surface [32]. Nawas, Wagner and GrÖtz found that moderately rough implants show a median Bone-implant-contact, which is 8% higher than the minimally rough implants [33].

Surface treatment procedures with calcium deposition on the surface have shown a steady increase in bioactivity with time, with maximum deposition in sandblasted, acid-etched, and thermally oxidized group. Increased surface roughness is known to enhance cell adhesion, proliferation, and differentiation. Kumar., *et al*. increased the surface roughness of implant by various methods such as machining, plasma spray coating, grit blasting, acid etching, sandblasting and acid etching (SLA), anodizing and biomimetic coating. They found that oxidation procedure performed on the SLA surfaces reduced the carbon concentration and consequently increase the oxygen concentration, which is related to the increased number of hydroxylated groups bound to the surface [34]. Soskolne., *et al.* found that the number of monocytes attached to blasted titanium surfaces was significantly more compared to machined surfaces [35]. Plasma spray coating generally forms a thick layer of deposition such as hydroxyapatite (HA) and titanium by spraying a material dissolved in heat on the surface of implant.

Grit blasting is one of the most commonly used method wherein implants are blasted wit healing. Surface coating of Hydroxyapatite has also been tried with Plasma spraying or h air-propelled hard ceramic particles. Depending on size of ceramic particles and their velocity, different surface roughness levels can be produced on implant surface [36,37]. Surface treatments of implants helps to provide strong bone implant anchorage and rapid Pulsed Laser deposition. The adhesive strengths of these coatings to substrate titanium alloy are being tested. The main advantage of this coating is that it inhibits the release of metal ions, which interferes in the process of osseointegration and thus leading to loss of bone around the implant site. Also, these coatings promote earlier and stronger fixation of implant but exhibit

Study by	Method	Implants	Load	Conclusion
Al Nawas B., *et al*. (2008)	Beagle dogs (32 implants of each type, n = 160); RFA	Branemark implants- machined MKIII, Ti Unite MK III, MK IV Straumann implants- Sandblasted, Acid etched and Ti plasma sprayed	Loading of 3 months	No difference between Branemark and Straumann implants
Butz F., *et al*. (2006)	Rats (n = 32); EDX and Micro CT	Acid etched and machined implants	2 - 4 weeks of loading	1. Hypothesized that implant surface roughness alter intrinsic biomechanical properties of bone 2. Bone integrated to acid etched Ti was approx 3 times harder than machined
Soskolne E., *et al*. (2002)	1640 culture media used	Ti discs were used for culture		1. Surface roughness of Ti discs increased with increasing size of blasting media 2. Rougher implant surfaces are more sensitive to contamination than smooth
Kumar Aswini., *et al*. (2005)	SEM, Surface Profilometer	Total of 100 implants were used divided into 4 groups Group A- Machined implants with no surface treatment Group B- Sandblasted and acid etched Group C- Modified sandblasted and acid etched Group D- Sandblasted, acid etched and thermally oxidized		This *in vitro* study concluded that thermally oxidized implant surface had better early bioactivity compared to machined, sandblasted and acid etched and modified sandblasted and acid etched surfaces
Gurzawska K., *et al*. (2012)		Nanocoating of organic molecules like Carbon and grapheme with surface modifications with Polysaccharides and glycosaminoglycans		1. Effective way to stimulate bone regeneration 2. Increased BIC length and bone mineral density adjacent to polysaccharides coating surfaces.

Table 5: *List of studies showing efffect of surface treatments on stability of dental implants.*

a durability that can be related to coating quality [38]. Vasanthan., *et al.* analysing implants using SEM found that PLD coatings were approximately 1 - 3 μm thick, whereas the plasma sprayed coatings were about 30 - 50 μm thick. In the same study the bond strength test of PLD coatings was significantly higher than that of plasma sprayed coatings. At the same time, they found out that PLD coatings did not alter the surface roughness of the substrate alloy significantly, which is an advantage for increasing the potential for bone ingrowth, greater bone-to-implant contact and rapid osseointegration [39]. Gurzawska., *et al*. in the ongoing research have speculated that Nanocoatings of organic molecules like carbon and graphene along with Surface modifications with Polysaccharides and glycosaminoglycans appear to be an effective way to stimulate bone regeneration on Bone implant interface [5].

Conclusion

With this review article it was observed that when placed in conditions of moderate bone density, conical implants with wide pitch achieved a small initial advantage as compared with semiconical implants with narrow pitch and after 90 days, both implant designs showed a similar primary stability as measured by RFA. The rough-surfaced dental implants have significantly higher success rates compared with smoother surfaced implants. Regarding surface treatment procedures, it was observed that Calcium deposition on the surface showed a steady increase bioactivity with time, with maximum deposition in sandblasted, acid-etched, and thermally oxidized group.

Hence it can be well stated that implant design plays an influential role in achieving primary stability of the implant.

Bibliography

1. Sergio Alexander Gehrke., *et al*. "Does Implant design affects Implant Primary Stability? A resonance frequency analysis-Based Randomized Split-Mouth clinical trial". *Journal of Implantology* 41.6 (2015): e281-286.
2. Gerard M Scortecci and Carl E Misch. "Implants and Restorative Dentistry. Introduction to oral Implantology in restorative dentistry". Martin Dunitz 11.
3. Javed F and Romanos GE. "Impact of diabetes mellitus and glycemic control on the osseointegration of dental implants, A systemic literature review". *Journal of Periodontology* 80.11 (2009): 1719-1730.
4. Yoko Yamaguchi., *et al*. "Effect of implant design on primary stability using torque-time curves in artificial bone". *International Journal of Implant Dentistry* 1.1 (2018): 21.
5. Gurzawska K., *et al*. "Nanocoating of titanium implant surfaces with organic molecules Polysaccharides including glycosaminoglycans". *Journal of Biomedical Nanotechnology* 8.6 (2012): 1012-1024.
6. Fawad Javed., *et al*. "Implant Surface Morphology and Primary Stability: Is There a Connection?" *Implant Dentistry* 20.1 (2011): 40-46.
7. Tabassum A., *et al*. "Influence of surgical technique and surface roughness on primary stability of an implant in artificial bone with different cortical thickness: A laboratory study". *Clinical Oral Implant Research* 20.4 (2009): 327-332.
8. Dos Santos MV., *et al*. "The effect of superficial roughness and design on primary stability of implants". *Clinical Implant Dentistry and Related Research* 13.3 (2011): 215-223.
9. Balshee AA., *et al*. "A retrospective study of the survival of smooth and rough surface dental implants". *International Journal of Oral and Maxillofacial Implants* 24.6 (2009): 1113-1118.
10. Albrektsson T., *et al*. "The long-term efficacy of currently used dental implants- A review and proposed criteria of success". *International Journal of Oral and Maxillofacial Implants* 1.1 (1986): 11-25.
11. Salvi GE and Lang NP. "Diagnostic Parameters for monitoring Peri-implant Conditions". *International Journal of Oral and Maxillofacial Implants* 19 (2004): 116-127.
12. Boggan RS., *et al*. "Influence of hex geometry and prosthetic table width on static and fatigue strength of dental implants". *Journal of Prosthetic Dentistry* 82.4 (1999): 436-440.
13. Geng JP., *et al*. "Finite element analysis of four thread-form configurations in a stepped screw". *Journal of Oral Rehabilitation* 31.3 (2004): 233-239.
14. Chang PK., *et al*. "Distribution of micromotion in implants and alveolar bone with different thread profiles in immediate loading: a finite element study". *International Journal of Oral and Maxillofacial Implants* 27.6 (2012): e96-e101.
15. Chun HJ., *et al*. "Evaluation of design parameters of osseointegrated dental implants using finite element analysis". *Journal of Oral Rehabilitation* 29.6 (2002): 565-574.
16. Arnhart C., *et al*. "Comparison of variable-thread tapered implant designs to a standard tapered implant design after immediate loading. A 3-year multicentre randomised controlled trial". *European Journal of Oral Implantology* 5.2 (2012): 123-136.
17. Jones FD. "Machine Shop Training Course". Industrial Press (1964).
18. Abuhussein H., *et al*. "The effect of thread pattern upon implant osseointegration". *Clinical Oral Implants Research* 21.2 (2010): 129-136.
19. Steigenga JT., *et al*. "Dental implant design and its relationship to long-term implant success". *Implant Dentistry* 12.4 (2003): 306-317.
20. Chung SH., *et al*. "Effects of implant geometry and surface treatment on osseointegration after functional loading: a dog study". *Journal of Oral Rehabilitation* 35.3 (2008): 229-236.
21. Motoyoshi M., *et al*. "Biomechanical effect of abutment on stability of orthodontic mini-implants. A finite element analysis". *Clinical Oral Implants Research* 16.4 (2005): 480-485.
22. Ma P., *et al*. "Influence of helix angle and density on primary stability of immediately loaded dental implants: three-dimensional finite element analysis". *Zhonghua Kou Qiang Yi Xue Za Zhi* 42.10 (2007): 618-621.

23. Misch CE., *et al*. "Scientific rationale for dental implant design". In: Misch CE, ed. Contemporary Implant Dentistry. 3rd edition. St. Louis Mosby (2008): 200-229.

24. Ao J., *et al*. "Optimal design of thread height and width on an immediately loaded cylinder implant: a finite element analysis". *Computers in Biology and Medicine* 40.8 (2010): 681-686.

25. Kong L., *et al*. "Evaluation of cylinder implant thread height and width: a 3-dimensional finite elemental analysis". *International Journal of Oral and Maxillofacial Implants* 23.1 (2008): 65-74.

26. Schrontenboer J., *et al*. "Effect of microthreads and platform switching on crestal bone stress levels: a finite element analysis". *Journal of Periodontology* 79.11 (2008): 2166-2172.

27. Lee DW., *et al*. "Effect of microthread on the maintenance of marginal bone level: a 3-year prospective study". *Clinical Oral Implants Research* 18.4 (2007): 465-470.

28. Amid R., *et al*. "Effect of microthread design of dental implants on stress and strain patterns: a 3-dimensional finite elemental analysis". *Biomedizinische Technik* 58.5 (2013): 457-467.

29. Lemons J. "Biomaterials in Implant Dentistry Contemporary Implant Dentistry". St. Louis: Mosby.

30. Janine W., *et al*. "Comparison between tapered and cylindrical implants in the posterior regions of the mandible: A prospective, randomized, split-mouth clinical trial focusing on implant stability changes during early healing". *Clinical Implant Dentistry and Related Research* 19.4 (2017): 733-741.

31. Von Wilmowsky C., *et al*. "Implants in bone: part 1. A current overview about tissue response, surface modifications and future perspective". *Journal of Oral and Maxillofacial Surgery* 18.3 (2014): 243-257.

32. Butz F., *et al*. "Harder and stiffer bone osseointegrated to roughened Titanium". *Journal of Dental Research* 85.6 (2006): 560-565.

33. Al-Nawas B., *et al*. "Insertion torque and resonance frequency analysis of dental implant systems in an animal model with loaded implants". *International Journal of Oral and Maxillofacial Implants* 21.5 (2008): 726-732.

34. Aswini Kumar K., *et al*. "Bioactivity and surface characteristics of Titanium Implants Following various surface treatments: An In vitro study". *Journal of Oral Implantology* 41.5 (2015): e183-e188.

35. Soskolne W., *et al*. "The effect of titanium surface roughness on the adhesion of monocytes and their secretion of TNF-alpha and PGE2". *Clinical Oral Implant Research* 13.1 (2002): 86-93.

36. Keren Shemtov-Yona and Daniel Rittel. "An overview of the mechanical integrity of dental implants". *BioMed Research International* (2015): 547384.

37. LeGuehennec A., *et al*. "Surface treatments of Titanium dental implants for rapid osseointegration". *Clinical Oral Implants Research* (2008).

38. Zeng H and Lacefield WR. "The study of surface transformation of Pulsed Laser Deposited Hydroxyapatite coatings". *Journal of Biomedical Materials Research* 50.2 (2000): 239-247.

39. Asvin Vasanthan., *et al*. "Implant Surface Modifications using Laser Guided Coatings: In Vitro Comparison of Mechanical properties". *Journal of Prosthodontics* 17.5 (2008): 357-364.

Volume 18 Issue 3 March 2019