CLINICAL ORAL IMPLANTS RESEARCH

Review

The effect of thread pattern upon implant osseointegration

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Abstract

Objectives: Implant design features such as macro- and micro-design may influence overall implant success. Limited information is currently available. Therefore, it is the purpose of this paper to examine these factors such as thread pitch, thread geometry, helix angle, thread depth and width as well as implant crestal module may affect implant stability.

Search Strategy: A literature search was conducted using MEDLINE to identify studies, from simulated laboratory models, animal, to human, related to this topic using the keywords of implant thread, implant macrodesign, thread pitch, thread geometry, helix angle, thread depth, thread width and implant crestal module.

Results: The results showed how thread geometry affects the distribution of stress forces around the implant. A decreased thread pitch may positively influence implant stability. Excess helix angles in spite of a faster insertion may jeopardize the ability of implants to sustain axial load. Deeper threads seem to have an important effect on the stabilization in poorer bone quality situations. The addition of threads or microthreads up to the crestal module of an implant might provide a potential positive contribution on bone-to to-implant contact as well as on the preservation of marginal bone; nonetheless this remains to be determined.

Conclusions: Appraising the current literature on this subject and combining existing data to verify the presence of any association between the selected characteristics may be critical in the achievement of overall implant success.

Implants could be considered predictable tools for replacing missing teeth or teeth that are irrational to treat (Lang & Salvi 2008). Implants are in fact between the most successful treatments used in medicine and their survival rates are known to exceed 95% in most of the published long-term (6, 10 or 13 years) studies (Haas et al. 1995; Goodacre et al. 2003; Fugazzotto 2005). However, the number of failures is still relevant and limiting these failures remains one of the goals in today's implant research.

Today, implant success is evaluated from the esthetic and mechanical perspectives. Both depend on the degree and integrity of the bond created between the implant and the surrounding bone. Many factors have been found to influence this interfacial bonding between the implant and bone and thus the success of implants. Albrektsson et al. (1981) reported factors such as, surgical technique, host bed, implant design, implant surface, material biocompatibility and loading conditions have all been showed to affect implant osseointegration.

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Studies to comprehend these factors and how they all influence each other have been the focus of recent literature. Understanding these factors and applying them appropriately in the science of dental implants can lead us to achieve predictable osseointegration thus minimizing potential implant failures. With this knowledge implant therapy could be easily applied even in the less favorable situations (e.g., early-immediate loading, smokers, diabetics or unfavorable bone quality).

A review of the literature that focuses on the relationship between osseointegration and the mechanical features of dental implant engineering is essential. Implant design, thread shape and pitch distance are factors to consider when selecting implant characteristics that would aid in different clinical conditions.

A literature search was conducted using MEDLINE to identify studies, from simulated laboratory models, to animal and human studies, related to this topic. The keywords of implant thread, implant macrodesign, thread pitch, thread geometry, helix angle, thread depth, thread width and implant crestal module were used. Table 1 lists currently available literature in this field based upon the search results.

Two main hypotheses theorized the elements affecting the attainment and maintenance of osseointegration. The 'biological hypothesis' focuses on the effect of bacterial plaque and host response patterns on implant survival. The 'biomechanical hypothesis' emphasizes occlusal overload on the supporting bone and the effect of compressive, tensile and shear forces on osseointegration.

Possible explanations for implant failure have been reported including micromovement, surgical trauma, bacterial infection, excessive load and impaired healing because of systemic diseases (Table 2).

Implant design features are one of the most fundamental elements that have an effect on implant primary stability and implant ability to sustain loading during or after osseointegration. Implant design can be divided into the two major categories: macrodesign and microdesign. Macrodesign includes thread, body shape and thread design [e.g., thread geometry, face angle, thread pitch, thread depth (height), thickness (width) or thread helix angle] (Geng et al. 2004a, 2004b). Microdesign constitutes implant materials, surface morphology and surface coating.

In this paper, we discussed mainly the effect of implant macrodesign features (Fig. 1) and their ability in influencing implant osseointegration. Particular attention was given to thread related characteristics (or thread geometry) such as thread shape, thread pitch, depth, thickness, face angle and helix.

Thread shape is determined by the thread thickness and thread face angle. Thread shapes available include; V-shape, square shape, buttress and reverse buttress shape (Boggan et al. 1999). Thread shape determines the face angle.

The *face angle* is the angle between a face of a thread and a plane perpendicular to the long axis of the implant. In the implant literature the most studied face angle is that of the apical face where most of the loading forces are dissipated.

Thread pitch refers to the distance from the center of the thread to the center of the next thread, measured parallel to the axis of a screw (Jones 1964). It may be calculated by dividing unit length by the number of threads (Misch et al. 2008). In implants with equal length, the smaller the pitch the more threads there are.

The *thread depth* is defined as the distance from the tip of the thread to the body of the implant.

Thread width is the distance in the same axial plane between the coronal most and the apical most part at the tip of a single thread.

Thread shape

In general, bone is constantly remodeling itself to adapt to external stimuli in the surrounding environment, which is known as bone homeostasis. In 1892, Wolff (1892) observed a direct association between bone form and mechanical loading and proposed his theory that 'every change in the form and function of bone or its function alone is followed by certain definite changes in the external conformation of bone, in accordance with mathematical laws. His theory entails that with increasing stresses new bone formation occurs, while a decreased stress leads to bone loss. However, other authors have questioned this theory after demonstrating that bone resorption also occurs under extreme stresses (Frost 1990). Hence, implant threads should be designed to maximize the delivery of optimal favorable stresses while minimizing the amount of extreme adverse stresses to the bone implant interface. In addition, implant threads should allow for better stability and more implant surface contact area.

Amount of force

Functional occlusal loading on an implant triggers the remodeling of the surrounding alveolar bone. A mild load induces a bone remodeling response and reactive woven bone production. However, excessive load result in microfractures which in turn causes osteoclastogenesis (Hansson & Werke 2003). When the bone remodeling capacity is insufficient to keep pace with the microdamage, these defects accumulate and coalesce to form a bigger defect (Prendergast & Huiskes 1996). As a consequence, the defect formed will fill with fibrous tissues and microorganisms (Misch et al. 2001). Eventually, severe bone loss occurs, decreasing the bony support around the implant and increasing the risk of implant failure (Brunski 1999).

Studies have utilized finite element analysis (FEA) to understand how thread profile may affect the stress concentration and distribution. This method allows studies to predict stress distribution between implants and cortical as well as cancellous bone (Bumgardner et al. 2000; Misch 2008). Using FEA, Geng and colleagues compared different thread configurations for an experimental stepped screwed implant. Out of the different thread designs tested, V-shape and the broader square shape generated significantly less stress compared with the thin and narrower square thread in cancellous bone. Cortical bone showed no difference among threads. Thus, both thread designs are more favorable configurations for dental implants especially when dealing with cancellous bone (Geng et al. 2004a, 2004b). Furthermore, other FEA studies also suggested a superiority of the square thread because it had the least stress concentration when compared with other thread shapes (Chun et al. 2002). However, the results of the above studies have to be carefully interpreted.

***Table 1*. Currently available literature associated with implant macrodesign features**

Authors	Method	Implants	Bone	Load	Conclusion
Thread design					
Geng et al. (2004a, 2004b)	FEA	Stepped screw V-thread, thin thread, thin square thread, thick square thread	2 models of cortical and trabecular bone	Oblique and vertical	Thread configuration had an effect on stress distribution only on trabecular bone
Chun et al. (2002)	FEA	Plateau type, plateau with small radius of curvature, triangular, square and square filleted with small radius	Jaw bone model	100 N axial and 15°	Plateau shape had maximum effective stress, square thread filleted with small radius had minimum stress
Steigenga et al. (2004)	Tibia, Rabbits	Square thread, V-shaped and reverse buttress	Natural bone: cortical and cancellous	No intentional loading	Square-thread design achieved greater BIC
Thread pitch					
Roberts et al. (1984)	Femur, rabbits	V-shape threads	Natural bone: cortical and cancellous	100 grams horizontal	The lower the pitch the higher the BIC
Ma et al. (2007)	FEA	Identical implants with different thread pitches (0.8, 1.6, 2.4 mm)		Vertical and horizontal loading	0.8 mm pitch showed a stronger resistance to vertical load
Chung et al. (2008)	Beagle dogs	3 groups of implants with different pitch height (0.5 vs. 0.6 mm	Natural bone: cortical and cancellous	6–12 months of loading	0.6 mm pitch had more crestal bone loss than the 0.5 mm pitch
Chun et al. (2002)	FEA	Plateau type, plateau with small radius of curvature, triangular, square and square filleted with small radius	Jaw bone model	100 N axial and 15°	Effective stress decreases as screw pitch decreases and as implant length increases.
Kong et al. (2006)	FEA	V-shaped thread	Jaw bone models	Axial load and bucco-lingual load	Stress decrease between pitch decreased from 1.6 to 0.8 mm then it increases when it is lower than 0.8 mm. Stresses are more sensitive to thread pitch in cancellous bone
Motoyoshi et al. (2005)	FEA	Titanium mini-implants with thread pitches from 0.5 to 1.5 mm	Cortical bone	Traction force of 2 N 45° to the bone surface	No difference when no abutment was connected. When the abutment was connected the best stress distribution was related to the lower pitch distance
Liang et al. (2002)	FEA				Implant length had higher influence than thread pitch on stress distribution
Thread helix angle					
Ma et al. (2007)	FEA	Identical implants with different thread pitches (0.8, 1.6, 2.4 mm)		Vertical and horizontal loading	Single (lower face angle) threaded is more stable than double threaded. Triple (higher face angle) threaded is the least stable thread
Thread depth and width					
Kong et al. (2006)	FEA	V-shaped threaded implants with thread heights of 0.2–0.6 mm and thread widths of 0.1–0.4 mm	Jaw bone models	100 N and 50 N of force axial (0° angle) and 45° angle	Optimal height: 0.34–0.5 mm optimal width: 0.18–0.3 mm In cancellous bone higher stresses were generated. 45° angle generated more stress than axial load
Crestal module					
Schrotenboer et al. (2008)	FEA	Implants with microthreaded crestal module vs. smooth neck	Model of a premolar region of the mandible	100 N at 90° vertical and 15° oblique angle	Increase bone stress in the microthreaded implants
Abrahamsson & Berglundh (2006)	Beagle dogs	Similar implant w/ microthreaded or smooth crestal module	Natural bone: cortical and cancellous	In occlusion for 10 months	BIC in the coronal portion was higher in the microthreaded group (81.8%) than in the control group (72.8%)
Lee et al. (2007)	Human, 17 patients	Similar implant type w/ and w/ out microthreaded crestal module	Natural bone: cortical and cancellous	In occlusion. Follow-ups up to 3 years	Marginal bone loss was lower in the microthreaded group

BIC, bone-to to-implant contact; FEA, finite element analysis.

Table 2. **Factors contributing to early and late implant failure**

Early failure	Late failure
◆ Micromovement (lack of primary stability)	◆ Bacterial infection
• Short implants	• History of Periodontitis
• Narrow implants	• Smoking
• Early/immediate loading	• Neck of the implant
• Low-density bone (osteoporosis)	• One-piece vs. two-piece
◆ Surgical trauma	◆ Excessive load
• Overheating	• Inadequate restoration
• Compression osteonecrosis	• Short/narrow implants
• Infection	• Trauma
◆ Impaired healing	
• Smoking	
• Diabetes	
• Age	

These studies simulated laboratory models; thus the translation of these results from a computer-based mechanical model into a functioning biological environment might not truly reflect the outcome noted in the intra-oral cavity. Furthermore, the amount of force, force direction and bone quality are factors that are highly diverse and different from one person to another. These factors may affect the load transferred to the bone and implant interface. However, FEA analysis remains one of the tools that can be used as an inexpensive stepping stone before conducting the clinical research. The results of FEA analysis might pave the way for more sophisticated clinical research that would better reflect the clinical reality noted in patients.

Favorable forces

The type of force applied to the implant–bone interface may influence the degree and strength of osseointegration. Three types of loads are generated at the interface; compressive, tensile and shear forces (Misch et al. 2008). Studies have shown that compressive force has most favorable effects on the bone tissue. This type of force increases the bone density and thus increases its strength. While, tensile and shear forces have been shown to result in weaker bone with shear being the least beneficial (Misch et al. 2008). The type of force that is generated depends on the shape of the implant. Hence, an ideal implant design should provide a balance between compressive and tensile forces while minimizing shear force generation. For instance, tapered implants have been shown to produce more compressive force than cylindrical implants which have more shear forces (Lemons 1993). This may explain why some authors considered cylindrical implants had a higher implant failure rate than tapered screw implants (Misch et al. 2008). Implant thread shape has also been found to influence the type of force transferred to the surrounding bone. Thread shapes available in the market today include; V-shape, square shape, buttress, reverse buttress and spiral shape (Fig. 2). Depending on the shape, different face angles, thread widths and forces generated are observed.

It has been reported that the face angle of the thread could change the direction of force at the bone/implant interface (Bumgardner et al. 2000). The amount of shear force generated by the different thread shapes increases as the thread face angle increases. Misch et al. (2008) suggested that V and reverse buttress thread have 30° and 15° angle, respectively. Hence V-shape threads generate higher shear force than both reverse buttress and square thread, with square thread generating the least shear force. Implants with V-shaped and buttress threads have been shown to generate forces which may lead to defect formation (Hansson & Werke 2003). In squared and buttress threads, the axial load of these implants are mostly dissipated through compressive force (Barbier & Schepers 1997; Bumgardner et al. 2000), while V-shaped and reverse buttress-threaded implants transmit axial force through a combination of compressive, tensile and shear forces (Misch et al. 2008) (Fig. 3).

Different studies evaluated the pattern of distribution of bone-to-implant contact (BIC) around threads. It was found that while not loaded, bone density was equally distributed above and below the thread. When under dynamic loading, bone density was higher below the threads and only weakest on the tip of the threads (Kohn 1992; Duyck et al. 2001; Bolind et al. 2005). This implies a correlation between compressive forces and bone strength. Furthermore, square thread implants were found to have greater BIC and higher reverse torque when compared with V-shaped and reverse buttress implants (Steigenga et al. 2004). Although this was an animal study, implants were never loaded and only the cortical area was considered region of interest. Nonetheless, this is one of the few studies that used an actual *in vivo* model.

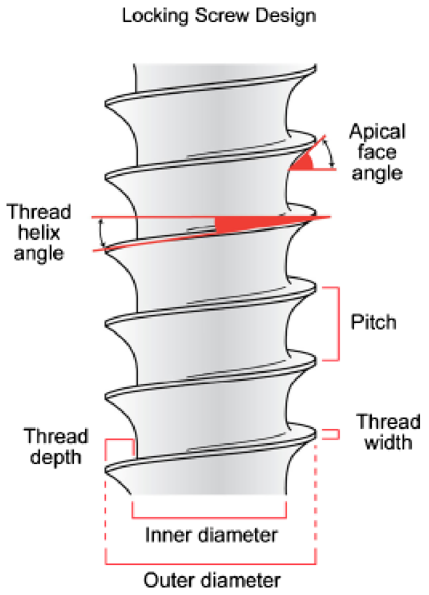

Fig. 1. Basic implant macrodesign features: face angle, thread helix, thread pitch, thread depth, thread width and inner and outer implant diameter.

Thread pitch

As previously mentioned, pitch distance is inversely related to the number of threads in the unit area. Pitch is in fact, the distance from the center of the thread to the center of the *next* thread, measured parallel to the axis of a screw. It differs from *lead*, which is the distance from the center of the thread to the center of the *same* thread after one turn or, more accurately, the distance that a screw would advance in the axial direction if turned one complete revolution. In a single-threaded screw, *lead* is

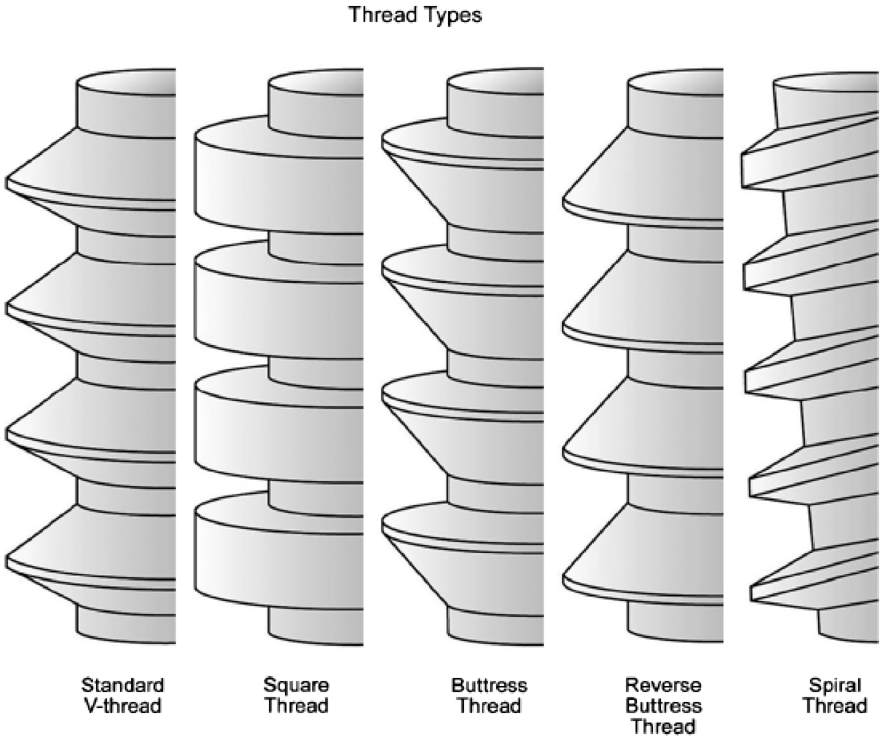

Fig. 2. Currently available implant thread pattern types.: V-thread, sqaure thread, buttress thread, reverse buttress thread and spiral thread.

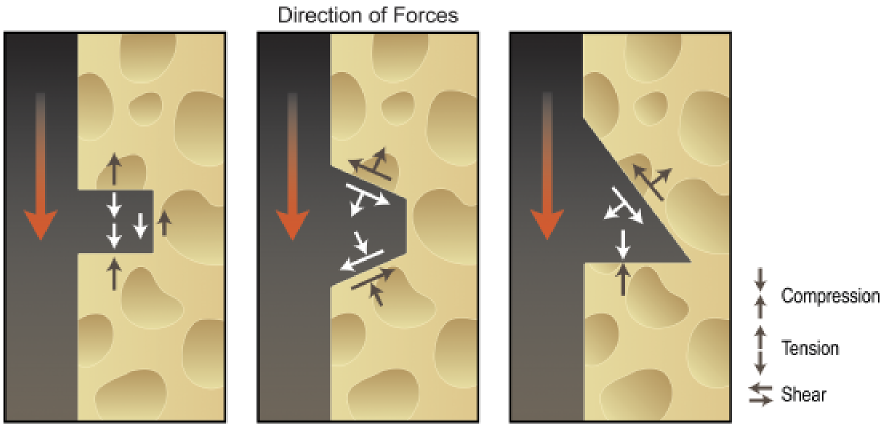

Fig. 3. Direction of forces generated at the implant and bone interface resulting from axial loading.

equal to *pitch*, however in a double-threaded screw, *lead* is double the *pitch* and in a triple-threaded *lead* is triple the *pitch* (Fig. 4). The lead basically determines the speed in which an implant will be placed in bone, if all other conditions are equal (e.g., pitch distance). An implant with double threads would insert twice as fast the single threaded and the triple threaded would only need a third of the required time for a single thread.

Studies found that implants with more threads (lower pitch) had a higher percentage of BIC (Roberts et al. 1984). Ma et al. (2007) using three-dimensional (3D)-FEA showed a 0.8 mm pitch had a stronger resistance to vertical load than those with 1.6 and 2.4 mm pitch.

The pitch is considered to have a significant effect among implant design variables, because of its effect on surface area (Steigenga et al. 2003). Studies showed that maximum effective stress decreased as screw pitch decreased and implant length increased (Chun et al. 2002; Motoyoshi et al. 2005). Chung et al. (2008) found that implants with a pitch distance of 0.6 mm had more crestal bone loss than the implants with 0.5 mm pitch. Authors concluded that as pitch decreases, the surface area increases leading to a more favorable stress distribution. Interestingly, Kong et al. (2006) considered 0.8 mm as the optimal thread pitch for achieving primary stability and optimum stress production on cylindrical implants with V-shape threads. They found that a shorter or a longer pitch had unfavorable stress generation. Furthermore, they also indicated that stresses are more sensitive to thread pitch in cancellous bone than in cortical bone. In conclusion, thread pitch plays a greater role in protecting dental implant under axial load than under off-axial (e.g., bucco-lingual) load. The same results were also found when orthodontic mini screws were used. Shorter pitch distance (i.e., 0.5 mm) had more favorable stress distribution when compared with 1 and 1.5 mm pitch distances (Motoyoshi et al. 2005). They concluded that the maximum effective stress decreased as screw pitch decreased gradually.

When the ability of bone to resist stress is weakened, the choice of implant aids in increasing primary stability, such as higher number of threads, is advisable. These weakened conditions may include but not be limited to poor bone quality, short implants and areas with high occlusal forces.

In good quality bone, selection of a favorable pitch distance to dissipate occlusal load in long implants remains unclear. Interestingly, It has been reported that the difference of pitch distance had little influence on the stress value and concentration when compared with implant length (Liang et al. 2002).

Thread helix angle

In a single-threaded implant the pitch equals the lead (the length of insertion of an implant every time when it is turned 360°). Some manufacturers have introduced double or even triple-threaded implants where two or three threads run parallel one to the other. This allows a faster insertion of the implant theoretically maintaining a pitch distance more favorable for the mechanical strength of the bone–implant interface (i.e. a triple-threaded

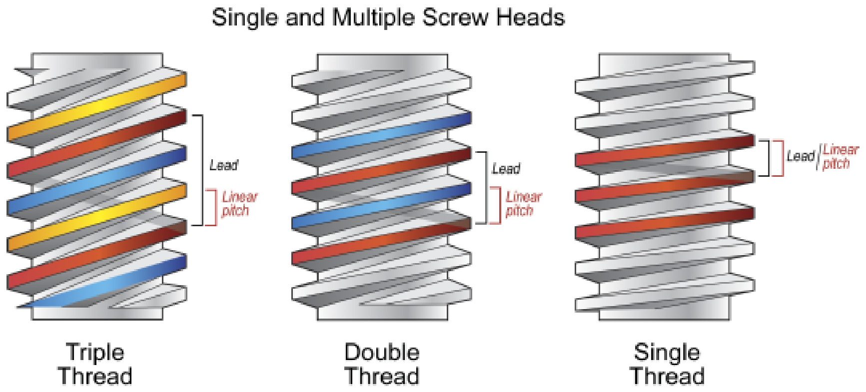

Fig. 4. This figure illustrates the thread configuration in relation to thread number, pitch and lead. Single-threaded implants have an equal thread pitch and lead. Double-threaded implants have a lead that is double the pitch. Triple-threaded implants have a lead that is triple the pitch.

implant with a pitch distance of 0.6 mm will be inserted 1.8 mm every time it is rotated 360°). However, it has to be considered that, as increasing the number of threads running parallel one to the other, the thread helix angle changes.

In a previously mentioned study from Ma et al. (2007), perfectly identical implants with different thread helix (single, double and triple threaded) were compared. These implants had a constant pitch of 0.8 mm, although the double- and triple-threaded implants had twice and triple the thread helix of the single-threaded implant, respectively. According to this FEA study, the most favorable configuration in terms of implant stability appeared to be the single-threaded one, followed by the double threaded. The triple threaded was found to be the least stable. In light of these results, it is suggested that a faster insertion of implant may actually compromise the final implant success.

Thread depth and width

Thread depth is the distance between the major and minor diameter of the thread (Misch et al. 2008). Thread width is the distance in the same axial plane between the coronal most and the apical most part, at the tip of a single thread. Both these designs have an effect on total implant surface area.

Given the same implant body, a shallow thread depth would allow for an easier implant insertion. Hence, it is agreed that 'the deeper the threads, the wider the surface area of the implant.' Greater thread depth may be an advantage in areas of softer bone and higher occlusal force because of the higher functional surface area in contact with bone. On the other hand, shallow thread depth permits easier insertion into denser bone with no need for tapping (Misch et al. 2008).

There is a commercially available implant system which is characterized by progressive threads (e.g., Ankylos, Dentsply Friadent, Mannheim, Germany), this means threads have higher depth in the apical portion and then decreases gradually coronally. This design might increase the load transfer to the more flexible cancellous bone instead of crestal cortical bone. Allegedly, this may contribute to less cortical bone resorption.

Thread height and width have been evaluated with the aim of finding the optimal thread configuration with minimal stress peaks (Kong et al. 2006). A 3D FEM using a V-shaped thread was created. Variations in thread height and width were set with a range of 0.2–0.6 mm and 0.1–0.4 mm, respectively. Forces of 100 and 50 N were applied parallel to the long axis of the implant and at a 45° angle. Results revealed that the optimal thread height ranged from 0.34 to 0.5 mm and thread width between 0.18 and 0.3 mm, with thread height being more sensitive to peak stresses than thread widths. In addition, maximum forces generated in cancellous bone were significantly higher than those generated in cortical bone. Also, 45° non-axial loads had higher stress than axial loads (Kong et al. 2006).

Crestal module

The neck of the implant is called crest module. Implant companies lately have concentrated their research on producing the best crest module features. This is because this area is where the implant meets the soft tissue and changes from a virtually sterile environment to an open oral cavity. Also, in this area the bone density is thicker (e.g., primary cortical bone) and therefore helpful to achieve or maintain implant primary stability. Furthermore, this is also the force concentrated area when the implant was put into function. (Mailath et al. 1989; Meijer et al. 1993; Steigenga et al. 2003). Bozkaya et al. (2004) compared implant systems with different thread profiles and crestal modules. They found moderate occlusal loads did not change the compact bone. However, when extreme occlusal loads were applied, overloading occurred near the superior region of the compact bone. Hence, the authors concluded that the crestal module may play a role in minimizing stresses to bone. In another study by Schrotenboer et al. (2008), they compared the effect of microthreads vs. smooth neck and platform switching vs. equal diameter abutment on crestal module. All of the used models demonstrated that stress was concentrated on the coronal portion of the bone crest. However, the stress type that is most favorable for crestal bone maintenance is still in debate. Wolff's law states that bone adapts to the loads when it is placed under stress. If loading on a particular bone increases, the bone will remodel to become stronger. If the loading on a bone decreases, the bone will become weaker because no stimulus is present. Many papers seem to suggest that the addition of threads on the neck of the implant may prevent future crestal loss. However, more studies are needed to confirm the results of these preliminary investigations.

Rough or smooth neck

Originally crest module was always smooth. The use of a smooth neck on rough implants came from the attempt to decrease plaque retention because the majority of the implants coronal portion was not embedded in bone. When the smooth portion of the implant is placed under the bone crest, increased shear forces are created resulting in marginal bone loss and eventually more pocket formation (Hermann et al. 2001;

Hanggi et al. 2005). When an implant with a smooth neck is selected, it should be placed over the bone crest. It has been shown that marginal bone loss around screw retained implants with a long smooth conical neck, is usually down to the first thread (Quirynen et al. 1992; Andersson 1995). Jung et al. (1996) evaluated bone loss around four different implants after 12 months of loading. He concluded that the bone level stabilized at the first thread of the implants with no correlation to either the time of exposure of the polished neck or the type of implant.

Table 3. **Implant design features and bone quality affecting the degree of primary stability**

Good bone quality	Increased primary stability
Long implant	
Wide diameter implant	
More threads	
Smaller pitch	
Deep threads	
Decreased thread helix angle	
Compromised bone quality	Decreased primary stability
Short implant	
Narrow diameter implant	
Fewer threads	
Longer pitch	
Shallow threads	
Increased thread helix angle	

Microthreads

Recently, the concept of microthreads in the crestal portion has been introduced to maintain marginal bone and soft tissues around the implants. Some authors attributed this bone loss to 'disuse atrophy' (Vaillancourt et al. 1995). In presence of a smooth neck, negligible forces are transmitted to the marginal bone leading to its resorption. However, the presence of retentive elements at the implant neck will dissipate some forces leading to the maintenance of the crestal bone height accordingly to Wolff's law (Hansson 1999). In a 2D FEA, Schrotenboer et al. (2008) found microthreaded implants increase bone stress at the crestal portion when compared with smooth neck implants. Palmer et al demonstrated maintenance of marginal bone levels with an implant that had retentive elements at the neck (e.g., Astra Tech AB, Mölndal, Sweden) (Palmer et al. 2000). In a dog model, Abrahamsson & Berglundh (2006) found increased BIC at 10 months in implants with microthreads in the coronal portion (81.8%) when compared with control non-microthreaded implants (72.8%). Lee et al. (2007) concluded a human study comparing implants with or without microthreads at the crestal portion. The authors indicated that addition of this retention element might have an effect in preventing marginal bone loss against loading. In this study many external variables were controlled and a statistically significant lower marginal bone loss was found around the microthreaded implants vs. the non-microthreaded ones. A critique of this study is that the microthreaded implant was tapered in the crestal portion and had, therefore, a wider coronal diameter. In general, the addition of threads or microthreads up to the crestal module of an implant might provide a potential positive contribution on BIC, as well as, on the preservation of marginal bone. Nonetheless this remains to be determined.

Conclusions

Few studies examined the *in vivo* effect of a particular feature in dental implant design on successful therapy. Simulated laboratory models (FEA) and other *in vitro* studies may differ from results found *in vivo*. Their results may not necessarily apply to the clinical setting. However, they represent the stepping stone in understanding the physical science around implants which need to be validated with further *in vivo* clinical studies.

In a clinical setting, consideration of specific implant design features in the decision making process, might contribute to the success of implant therapy. In situations with good bone quality and easily attainable primary stability, certain implant design features might not be as critical for success. However, when primary stability is a concern, for example; compromised bone quality or high occlusal stresses, increasing the implant surface area exposed to the surrounding bone by using implants with smaller pitch, more threads, deeper threads, decreased thread helix angle, a longer implant and/or a wider diameter may be beneficial (Table 3).

However, it has to be considered that when using a particular implant the effect of a single feature could be washed out by other elements of the particular design of the selected implant.

This literature review has been focusing on mechanical features. Strong emphasis has to be put in understanding that one sole factor will not account for success and that several other factors might have an effect on the treatment provided. This review is not intended to give clinicians a guideline on how to choose implants for everyday practice.

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