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Review Article

Effects of Implant Thread Design Around Tissues of Implant

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Abstract

To restore function and aesthetics, dental therapy tries to replace all or part of the diseased or damaged tooth structure. For this reason, a variety of techniques have been used throughout the years, and implants have recently gained popularity. Osteointegration, which occurs when the implant and surrounding bone come into direct touch, is thought to be the most important factor in determining the clinical effectiveness of dental implants.

Implants with a narrower pitch are advantageous when primary stability is a concern because they increase bone-implant contact. The ideal values of thread depth and breadth may vary based on thread form and other geometric parameters. Thread depth is more important than thread width for dispersing peak stresses inside the bone. For implants put in the cancellous bone and subjected to rapid loading, the micro thread arrangement at the implant neck may enhance bone growth and stress distribution.

The advantages of a single design element for a particular implant may be increased or diminished by the implant's other factors. such as mechanical characteristics and biological circumstances. Clinicians should take into account the fact that an implant's success and survival are not guaranteed by a single design element.

Keywords: Implant; Thread Design; Tissues

Introduction

The goal of dentistry has been to restore lost teeth ever since it was established as a profession. For years, dentists have relied on their own knowledge and a variety of artifacts to offer aesthetically pleasing and practical ways to lessen the effects of edentulism. The goal of contemporary dentistry is to restore the patient's natural shape, function, comfort, aesthetics, speech, and health, whether that means filling cavities in a single tooth or replacing several teeth. A prosthodontic foundation comprised of an alloplastic material called an endosteal implant is inserted surgically into a remaining bony ridge [1].

Osteointegration, which occurs when the implant and surrounding bone come into direct touch, is thought to be the most important factor in determining the clinical effectiveness of dental implants [2]. The materials used, such as implant length/diameter and microscopic/macroscopic morphology, the local bone tissue characteristics, such as bone quality/quantity and cortical bone thickness, and surgical/placement technique, such as drill size, implant size, pre-tapped or self-tapered implant, and use of osteotomes, are just a few of the variables that affect primary stability [3].

Components of an implant

A crest module (cervical geometry), a body, and an apex make up the implant body (Figure 1).

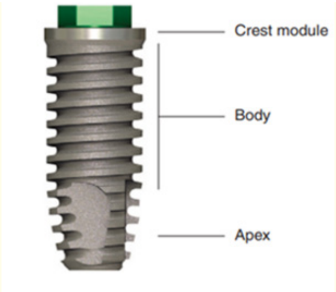

Figure 1: An implant body is the portion of the dental implant that is designed to be placed into the bone to anchor prosthetic components. The implant body has a crest module, a body, and an apex.

The primary purpose of an implant body is to facilitate surgery or to provide prosthetic loading to the implant-bone contact. A cylinder implant design system has the benefit of being easy to insert, even in hard-to-reach places. Before the implant is placed, the cover screw for the implant can also be connected to it.

Most cylinder implants are smooth-sided, bullet-shaped implants that need a bioactive or larger surface area covering for bone retention. The surface area of bone contact on an implant rises by more than 30% when these materials are used. The prosthesis support system is more effective the bigger the functional surface area of the bone-implant contact. The most often mentioned implant body design is a solid screw implant.

The power thread may be square, buttressed, reverse buttressed, or V-shaped in form. The V-shaped threaded screw has the finest therapeutic properties [4]. With a thread depth of 0.38 mm and a thread pitch of 0.6 mm, the most typical outer thread diameter is 3.75 mm. Although lengths of 5 mm to 56 mm are also offered, the body lengths commonly vary from 7 to 16 mm. To suit the mechanical, aesthetic, and anatomical requirements of various mouth regions, similar body designs are offered in a range of diameters (narrow, standard, and broad). The main goals of a threaded implant body are to increase the surface area of the bone-implant contact and lessen occlusal loading pressures.

The component intended to keep the prosthetic component in place in a one- or two-piece implant system is called the crest module. The platform, on which the abutment is typically situated, provides physical resistance to axial occlusal stresses in the abutment connection area. In contrast to the crest module, which is often meant to stop bacterial invasion, the implant body (such as threads or large spheres) is intended to transmit stress and strain to the bone during occlusal loading.

Implant surgery

A first-stage cover screw is inserted into the top of a two-stage implant body during stage I surgery to prevent bone, soft tissue, or debris from entering the abutment connection area during healing (Figure 2).

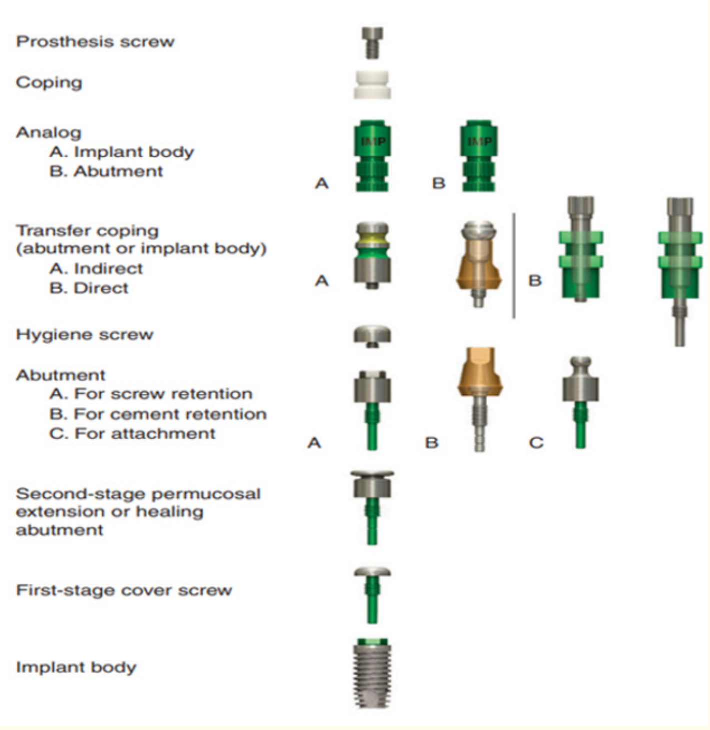

Figure 2: Implant components frequently have terms that are different for each company, but a generic language exists that applies to any product. This language permits improved communication between referring doctors and laboratories, which often must be familiar with several different systems.

A second-stage surgery may be conducted to expose the two-stage implant or to attach a permucosal extension, which is a transepithelial portion [5].

Prosthetic Attachments The component of the implant that supports or retains a prosthesis or implant superstructure is known as the abutment [5].

- An abutment for screw retention uses a screw to retain the prosthesis or superstructure (Figure 3, A).
- An abutment for cement retention uses dental cement to retain the prosthesis or superstructure (Figure 3, B)
- An abutment for attachment uses an attachment device to retain a removable prosthesis (such as an O-ring attachment) (Figure 3, C).

Each of the three abutment types may be further classified as straight or angled abutments, describing the axial relationship between the implant body and the abutment.

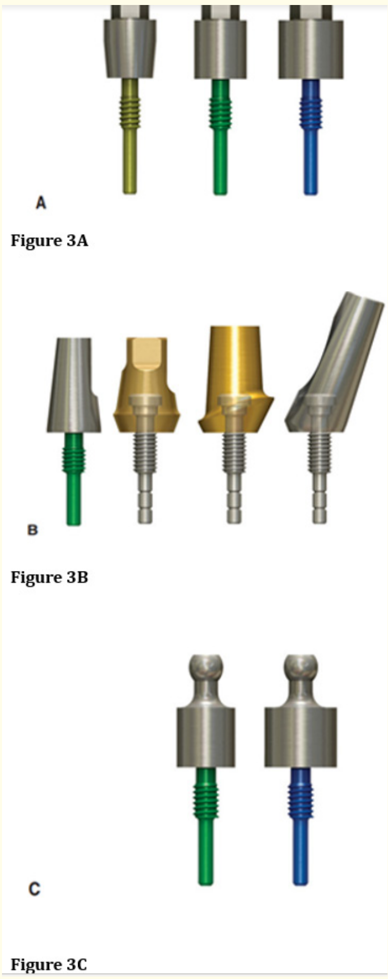

Figure 3

Figure 4

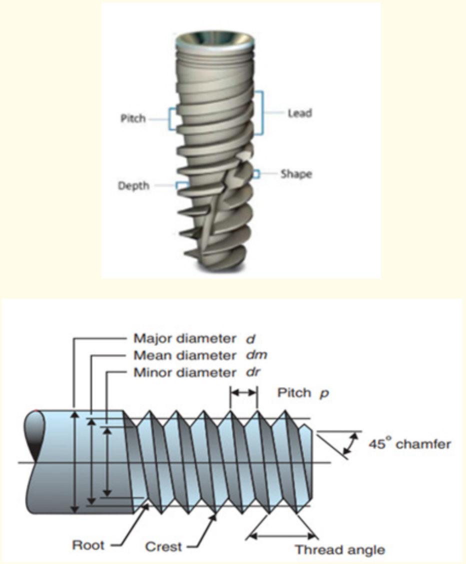

Figure 5: There are several parameters of an implant that may alter the functional surface area. Three of these include: thread pitch, thread shape, and thread depth.

Implant thread design

Currently, there are a variety of implant body forms that may be categorised as cylinder, screw, press fit, or a combination of characteristics. A friction fit is used during the insertion of cylinder or press fit implants, which lowers the danger of pressure necrosis brought on by too much insertion pressure.

Thread geometry

Threads are designed to maximize initial contact, enhance the surface area, and facilitate dissipation of loads at the bone-implant interface.[6] Functional surface area per unit length of the implant may be modified by varying three geometric thread parameters.

Thread pitch, thread shape, and thread depth and width.

Thread pitch

The thread pitch of an implant is the measurement of the distance in parallel between consecutive thread form elements [6]. Thread pitch is the measurement of the distance between adjacent threads taken along the same axis. The quantity of threads per unit length is also mentioned. If all other factors remain the same, the implant body will have more threads and, thus, more surface area per unit length, the smaller (or finer) the pitch. The number of threads per unit length will rise when the gap between threads is decreased. The more threads there are, assuming all other factors are equal, the larger the surface area (Figure 6)

Thread pitch and lead are two geometrical parameters. Lead is the amount a screw would move in the axial direction in one full revolution.

Several manufacturers (such as Zimmer and Nobel Biocare) promote implant bodies with multiple or triple thread leads. There is no connection between these phrases and a rise in the functional surface area; rather, they relate to the manufacturing process. Instead of cutting one thread at a time with a single cutting tool, a double thread requires two cutting blades, and a triple thread uses

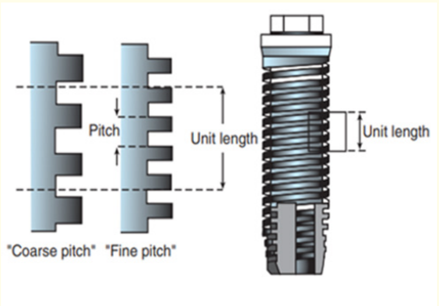

Figure 6: The thread pitch describes the number of threads per unit length of an implant. The implant on the right has a smaller thread pitch and greater surface area, whereas the implant on the left has the largest thread pitch and the least overall surface area.

three blades. In a single-threaded screw, lead is equal to pitch; however, in a double-threaded screw and a triple-threaded screw, lead is double the pitch and treble the pitch, respectively.

(Figure 7)

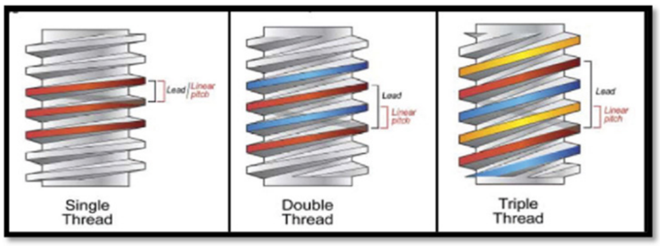

Figure 7.

Thread shape

Wolff hypothesised in 1892 that higher stresses lead to the formation of new bone whereas lower stresses lead to the loss of bone. Implant threads should be designed to minimise the amount of excessive unfavourable stresses while maximising the transmission of optimal favourable stresses to the bone implant interface. The surface contact area and implant stability should both be enhanced by implant threads [7].

Another crucial aspect of total thread geometry is thread shape.[6] The thread forms used in dental implant designs include square, V-shape, buttress, and reverse buttress, as was previously mentioned (Figure 8).

The face angle of the thread or plateau in an implant body can modify the direction of the occlusal force applied to the prosthesis and abutment connection at the bone contact. While the face angle of a square thread can be perpendicular to the long axis, the face angle of a V-shaped thread is 30 degrees off. Therefore, occlusal loads in the axial direction of an implant body may be compressive at the bone interface when the implant body incorporates square or plateau designs, but the occlusal loads can be changed to higher shear loads at the bone interface when the implant body incorporates V-shaped threads.[6] (Figure 9).

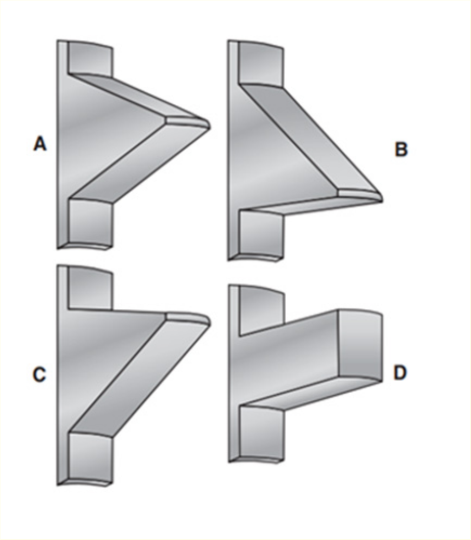

Figure 8: The four basic thread shapes for implant design include: (A) V-thread, (B) buttress thread, (C) reverse buttress thread, and (D) square thread.

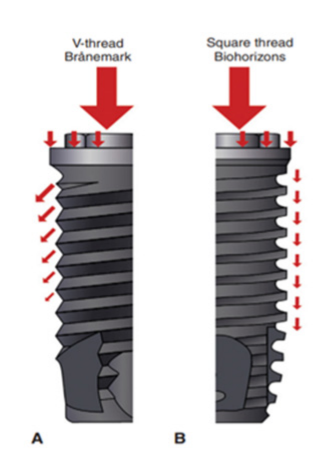

Figure 9: A: A long axis load to an implant body with V-thread with a 30-degree thread face converts the load direction to a 30-degree angle at the implant interface. An axial load on the prosthesis may result in an axial load to the implant platform. However, the implant body design may convert the primary compressive forces to the prosthesis and results in a 30-degree angled force with more tensile and shear loads to the implant-bone interface.
B: A plateau or square-thread design can deliver a compressive force to the bone when the implant is loaded in the long axis. The implant body design determines the type of force transmitted to the implant-bone interface.

Thread depth and width

Thread depth, according to Misch, is the distance between the thread's major and minor diameters. (Figure 10).

The distance between the thread's outermost tip and the implant's body is referred to as the thread depth.

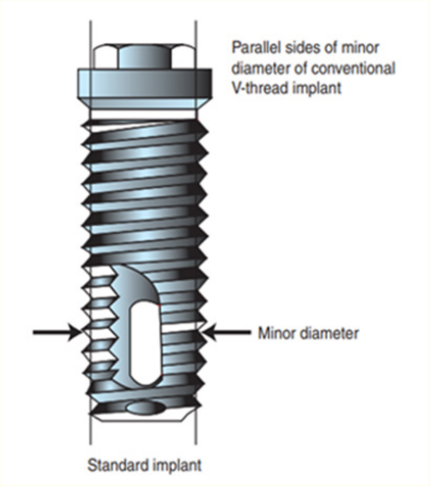

Figure 10: The thread depth of an implant refers to the distance between the outer (or major) diameter and the inner (or minor) diameter of the thread. The deeper the thread depth, the greater the functional surface area.

The distance in the same axial plane between the coronal and apical portions at the tip of a single thread is known as the thread width [7] (Figure 11).

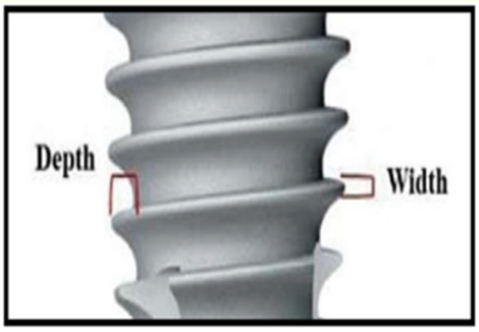

Figure 11

Traditional implants have a constant thread depth over their whole length. A parallel-walled implant length with a straight minor diameter produces a homogeneous cross-sectional area. This minor diameter is utilized in practically all screw type implants. A tapered implant frequently has a consistent minor diameter, but because of the taper, the outer diameter shrinks and the thread depth shrinks towards the apex.

For every mm increase in diameter, the implant's surface area rises by 15 to 25%. The body wall thickness between the inner diameter and the abutment screw space within the implant may increase as an implant widens without reducing the depth of the thread. As a result, for every 1mm increase in implant diameter, the thread depth may be changed relative to the implant's diameter, increasing the surface area overall by 150% [8].

The available literature on thread depth is summarized in table 1.

Study	Method	Thread depth and width	Load	Conclusion
Kong., *et al.* (2008)	FEA	Cylinder implants with height of 0.2 - 0.6 mm and width of 0.1 - 0.4 mm	100 N axial load and 50 N, 45° buccolingual load	The optimal values of thread depth and width were 0.34 - 0.5 mm and 0.18 -0.3 mm respectively. Thread depth was also a more sensitive factor to reduce the peak stress concentration within the bone.
Aoet., *et al.* (2010)	FEA	Cylinder implants with height of 0.2 - 0.6 mm and width of 0.1 - 0.4 mm	100 N axial load and 50 N, 45° buccolingual load	Thread depth affected the thread distribution more significantly than thread width. Threads with depths of more than 0.44 mm and width of 0.19 – 0.23 mm showed the most favourable results.

Table 1

Crest module

The crest module refers to the area of the implant that is in touch with the cortical bone close to the crest. The transosteal area, which extends from the implant body and frequently includes the anti-rotation components of the implant abutment connection, is the crest module of an implant body [9]. Where the implant hits the soft tissue is where the hostile oral cavity transitions from a nearly sterile environment. To completely seal the osteotomy and provide a barrier that prevents the admission of germs or fibrous tissue during early healing, an implant's crest module has to be somewhat bigger than the outside thread diameter of the implant body [9].

It is possible to infer the following clinical findings about several aspects of implant thread design: The square thread profile could offer the best main stability for thread shape. Implants with a narrower pitch are advantageous when primary stability is a concern because they increase bone-implant contact. The ideal values of thread depth and breadth may vary based on thread form and other geometric parameters. Thread depth is more important than thread width for dispersing peak stresses inside the bone. For implants put in the cancellous bone and subject to rapid loading, the micro thread design at the implant neck may enhance bone growth and stress distribution. (Table 2) lists a few implant systems that are offered in India along with their thread patterns.

V - thread	Branemark system (Nobel Biocare)
Square Thread	External Implant System (BioHorizon)
Buttress Thread	Straumann Standard
Reverse Buttress Thread	Nobel Replace (Nobel Biocare)
Square Thread	Adin Implant System
Buttress Thread	Genesis Implant System
Cylinder/Pressfit	Zimmer Implant System

Table 2: Data from histometric measurements are summarized.

Surgical failure

In the majority of cases, tapered screw-type body designs are to blame for excessive pressure during implant implantation. When adopting a tapered screw implant design, the insertion torque force may exert too much stress on the bone, leading to resorption and implant failure.

Another reason surgery fails is little movement of the implant while the developing interface is created.

Figure 12: Micromovement of a developing bone-implant interface may cause fibrous tissue to form around an implant rather than a bone-implant interface. Excessive stresses to an implant may cause overload and failure. This implant had occlusal overload, which resulted in fibrous tissue formation around the implant (From Isidor F: Loss of osseointegration caused by occlusal load of oral implants: a clinical and radiographic study in monkeys, Clin Oral Implants Res 7:143-152, 1996.).

Early loading failure

Sometimes, even after an implant has "integrated" with the bone, it might still fail. Prior to failure, the implant appears to be firmly attached, and all clinical indicators are within normal ranges. However, it takes the implant 6 to 18 months to become mobile once it has been loaded. This is referred described as "early loading failure" by Misch and Jividen [10]. The primary factor in early loading failure is typically excessive stress at the bone-implant interface.

Effect of implant thread design on soft tissue

The maintenance of healthy bone and soft tissue around a dental implant is one of the most challenging tasks an implantologist needs to perform. In particular, the thick keratinized oral epithelium that provides mechanical protection, the sulcular epithelium that forms next to the implant and provides cellular immunological protection, and the junctional epithelium that attaches to the titanium implant as a hemi desmosomal attachment and thus constitutes an essential component of the periodontal soft tissues, Schupbach and Glauser [11] have shown remarkable similarities between peri-implant and periodontal soft tissues.

Factors affecting peri implant soft tissue

The patient's overall health and age, the existence of keratinizing and connected mucosa, the presence of sufficient vestibular depth, and the periodontal state of the remaining dentition are some of the internal variables that affect the health of the soft tissue around the implant.

The use of tobacco, ensuring adequate soft tissue rest during healing, maintaining oral hygiene, preserving biologic width by positioning the restorative margin at least 0.5-1 mm away from the base of the sulcus, and factors related to implant placement are among the external factors that are deemed important.

First off [12], as it stops the soft tissue from collapsing and the alveolar bone from resorbing, the placement of the implant should happen as soon as possible after the loss of the tooth.

Second, in order to maintain the integrity of the soft tissue architecture, the implant's size should not be greater than that of the natural tooth it replaces. This rule applies 2 mm below the CEJ.

Thirdly, for buccolingual location, the implant should be positioned around 1 mm within the buccal bone to achieve a natural emergence profile.

Fourth, the implant's angulation with its centre emerging immediately under the incisal edge is desirable in terms of faciopalatal angulation.

Fifth [13], Pattrick and Erricson recommended that for a more realistic soft tissue draping, the crown abutment junction of the implant-supported restoration should roughly match with the CEJ of the neighbouring teeth.

Sixth, Tarnow., *et al.* [14]. recommended a minimum space between implants of 3 mm in order to protect crestal bone and soft tissue. The non-submerged technique does provide soft tissue predictability since it gives enough time for soft tissue integration, according to Sclar [15], who also noted that although the decision between the two approaches differed depending on the clinical scenario.

Biologic width changes around loaded implants inserted in different levels in relation to crestal bone

A research was done by Ana Emilia Farias Ponteset., *et al*. to assess the histometric alterations surrounding dental implants that were placed under various loading circumstances and at various levels in respect to the crestal bone.

The pursuing variables were assessed (Figure 13)

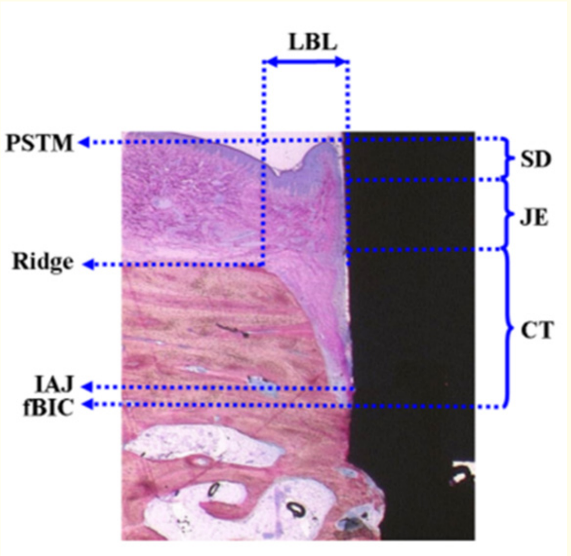

Figure 13: Schematic drawing illustrating the landmarks used for histometric analysis. CT, connective tissues; fBIC, first bone–implant contact; IAJ, implant–abutment junction; JE, junctional epithelium; LBL, lateral bone loss; PSTM, position of soft tissue margin; SD, sulcus depth.

- sulcus depth (SD), distance from the most coronal PSTM to the most coronal point of the junctional epithelium (JE).
- JE, distance from the most apical to the most coronal point of the JE.
- connective tissue attachment (CT), distance from the most apical point of the JE to the fBIC.
- PSTM-fBIC, distance from PSTM to fBIC.
- PSTM-IAJ, distance from PSTM to IAJ.
- IAJ-fBIC, distance from IAJ to fBIC.
- Ridge-fBIC, distance from the ridge to fBIC; and
- lateral bone loss, from the implant body to the ridge.

Data from histometric measurements are summarized.

Effects of Thread Depth in the Neck Area on Peri-Implant Hard and Soft Tissues

A deep-threaded implant (DT) and a shallow-threaded implant (ST) were the two implant types employed in this investigation.

The thread form was the only difference between the two implant types; the surfaces of both also possessed a nanostructured calcium coating. The implants had the following dimensions: The shallow-threaded implant has a diameter of 3.5 mm, a length of 7 mm, and a core diameter of 2.7 mm; the deep-threaded implant has a diameter of 5.5 mm, a length of 7 mm, and a core diameter of 3.2 mm.

The deep-threaded implant had a 1.15-mm depth and a 0.8-mm pitch, compared to the shallow-threaded implant's 0.4-mm depth and 0.8-mm pitch. The initial implant location was random. After that, implants were inserted alternately.

	Conventional restoration				Immediate restoration			
	Bone Level	Minus 1	Minus 2	P	Bone Level	Minus 1	Minus 2	P
SD	0.46 ± 0.17	0.65 ± 0.37	0.83 ± 0.46	NS	0.51 ± 0.18	0.43 ± 0.15	0.52 ± 0.17	NS
JE	0.94 ± 0.68	0.95 ± 0.67	0.92 ± 1.09	NS	0.85 ± 0.37	1.04 ± 1.18	0.97 ± 0.5	NS
CT	1.59 ± 0.39	1.90 ± 0.45	2.47 ± 0.88	NS	1.49 ± 0.55	2.24 ± 1.21	2.76 ± 1.15	NS
PSTM-fBIC	3 ± 0.9^{a}	3.50 ± 0.59^{b}	4.48 ± 1.04 ^{ab}	0.03	2.85 ± 0.6	3.71 ± 0.9	4.25 ± 1.41	NS

Table 3: Mean Values (mm ± standard deviation) for sulcus depth, junctional epithelium, connective tissues, and PSTM-fBIC.

Identical letters indicate statistically significant intergroup differences (P < 0.05, ANOVA test).

CT: Connective Tissue; Fbic, first bone implant contact; JE: Junctional Epithelium; PSTM: Position of Soft Tissue Margins; SD: Sulcus Depth; NS: Non-Significant.

	Conventional restoration				Immediate restoration			
	Bone Level	Minus 1	Minus 2	P	Bone Level	Minus 1	Minus 2	P
PSTM-IAJ	1.47 ± 0.97^{ab}	2.41 ± 0.79^{ac}	3.51 ± 0.89^{bc}	0.005	1.56 ± 0.81^{de}	3.04 ± 0.56^{d}	3.43 ± 1.4^{e}	0.01
IAJ-fBIC	1.46 ± 0.31	1.26 ± 0.43	1 ± 0.32	NS	1.54 ± 0.57	1.07 ± 0.73	0.82 ± 0.51	NS
Ridge fBIC	0.78 ± 0.37^{fg}	1.67 ± 0.7^{f}	2.02 ± 0.74^{g}	0.01	0.77 ± 0.32^{hi}	2.06 ± 0.55^{h}	2.42 ± 1.06^{i}	0.003
LBL	0.87 ± 0.42	1.33 ± 0.46	1.31 ± 0.32	NS	0.84 ± 0.23	1.08 ± 0.24	0.83 ± 0.28	NS

Table 2: Mean values (mm ± standard deviation) for PSTM-IAJ, Ridge fBIC, and LBL.

Identical letters indicate statistically significant intergroup differences (P < 0.05, ANOVA test)

IAJ: Implant-Abutment Junction; fBIC: First Bone Implant Contact; PSTM: Position of Soft Tissue Margins; NS: Non-Significant.

To evaluate marginal bone loss, intraoral radiographs were collected 3 months after each extraction (during implant implantation) and at the time of death.

The results of the current study showed that, despite the fact that deep thread depth is meant to increase the surface area available for implant-tissue contact and thereby potentially enhance osseointegration, our deep-threaded implant group temporarily had lower bone implant contact than our shallow-threaded implant group. Both our CT and histomorphometic studies at 4 weeks revealed the difference. By 8 weeks, there had been no discernible difference in the two groups' bone implant contact values.

Effect of implant thread design on hard tissue

In the first year of use, there will be 1.5 to 2 mm of bone resorption, which is typically regarded as a normal physiological process [16]. Following that, a typical yearly bone loss of 0.2 mm might be anticipated [17]. The neck configuration of the implant can lessen the minor bone loss.

Marginal bone loss is significantly influenced by surface properties as well. Because the un-roughened surface of the implants fails to evenly transfer occlusal stresses, most hybrid implants with micro-rings and flat surfaces exhibit alveolar bone loss throughout the whole length of the flat surface, up to the first thread [18]. However, implants with rough surfaces and micro-rings enable tissue ingrowth [19]. Depending on how the implant surface is treated, the surface microstructure varies, which can change how stress is distributed, how cells react to the implant surface, and how well the implant osseointegrates.

The effects of dental implant thread design on long-term marginal bone loss

There are several commercially available dental implant thread patterns. The thread design, in addition to affecting insertion torque and primary stability, can improve initial contact, disperse load pressures, and increase surface area at the bone-implant interface [20]. Marginal bone loss may also be impacted by implant shape.

In one research, however, two distinct thread designs were compared with two different surface treatments on the implants. In this study, marginal bone loss over a year was one of several characteristics examined to see how implant thread design and surface treatment affected those parameters. There were two implants assessed. The reverse buttress V-thread on one implant had a bigger pitch and a smaller face angle, whereas the V-shaped thread on the other implant had a lower pitch and a larger face angle. After a year of follow-up, there was a marginally favorable difference in bone loss favoring the V-shape thread.

A dog experimental study on tissue characteristics at micro-threaded implants

Marginal bone loss is a commonly reported characteristic in the assessment of dental implants, and many success criteria for implants have indicated threshold amounts of marginal bone loss [21]. Even while results from early clinical research suggested that marginal bone loss was more pronounced in the first year of function than in later years [22], similar patterns of bone loss have not been supported by more recent investigations [22].

The capacity to establish or maintain marginal bone support may be influenced by the geometry and surface roughness of the implant. When compared to normal implants of the same implant system, implants created with an unthreaded, conical marginal part and often employed in single-tooth replacements consistently showed an increased marginal bone loss [23]. It was hypothesized that geometry-related variations in bone loss between the two types of implants were responsible, and that implant portions with a conical design may experience less osseointegration.

Conclusion

The significance of the soft tissue interface, which creates the biological seal or barrier, has, nevertheless, come to be understood as a key component of implant success.

In conclusion, the implant variables, surgical technique, and host factors all have an impact on both the hard and soft tissue-implant interfaces. The success of dental implant therapy can be impacted by the quality of the tissue-implant interactions.

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