LaminOss Immediate-load Implants: I. Introducing Osteocompression in Dentistry

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Key Words

Sinusoidal thread design
Implant load-bearing areas
Bone lamination/osteocompression
Occlusal force to bone density classification

Osteocompression is a physiologic principle that has been clinically practiced in orthopedics since the early 1900s. In dentistry, controlled functional osteocompression is the compaction created by the tapping procedure and bone lamination achieved by a sinusoidal screw implant design providing physiologic stimulation due to streaming potentials. Functionally, there is always an applied force acting on bone modified by an implant design, and there is always a resisting force acting on the implant through the viscoelastic properties of trabecular structure. Through biomechanical events in bone, osseous tissue can be stimulated within physiologic limitations by implant design to develop along the lines of compressive forces dependent on the implant load-bearing area to sustain equilibrium. At the cellular level, these biomechanical events act on the cells through a phenomenon known as streaming potentials. This is an electrochemical potential created by the flow of extracellular fluid past a positively charged cell surface.

Streaming potentials have a stimulating effect on osteoblasts and osteocytes. This stimulation under acceptable physiologic limits translates to an ordered deposition of osseous tissue that aids in the support of these compressive forces.

As a sinusoidal thread design, the LaminOss osteocompressive immediate-load implant (Impladent Ltd, Holliswood, NY) has shown in animal histologic observation 2.5 times greater bone lamination achieved by the function of osteocompression due to the benefits of streaming potentials created by the LaminOss implant design. No evidence of bone necrosis was observed by any of the eight implants.

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Introduction

The LaminOss sinusoidal thread design, together with its surgical technique, provides an increase in bone lamination and volume for support as an immediate functioning implant. The increase of implant load-bearing areas (LBA; horizontal planes) and the controlled surgical osseous lamination technique excites bone cells by the action of osteocompression around the sinusoidal implant threads. This paper not only introduces osteocompression

TABLE 1

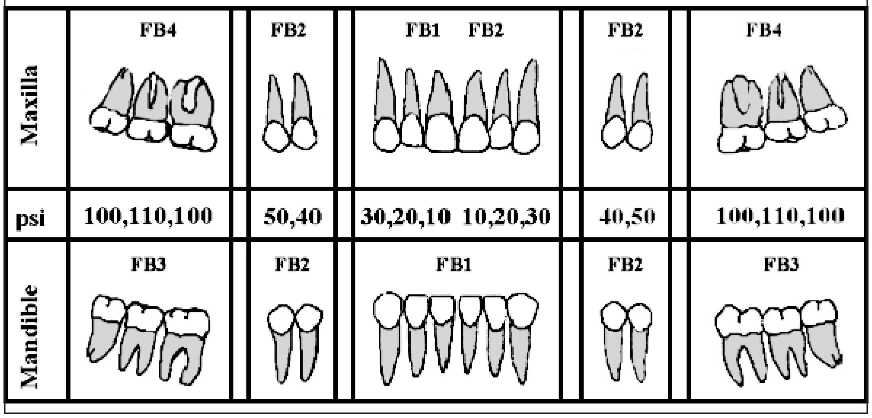
Bone-to-implant equilibrium under static load for ideal bone density*

Applied Force (Patient's Force Registration [PSI])	Resisting Force (Required Implant Load-Bearing Area [LBA]) (mm²)
Static Compressive Strength of Maxillary Cancellous Bone (10 MPA)	
1	0.444
5	2.220
10	4.445
15	6.670
20	8.900
25	11.120
30	13.350
35	15.570
40	17.790
45	20.020
50	22.240
Static Compressive Strength of Mandibular Cancellous Bone (15 MPA)	
1	0.296
5	1.480
10	2.970
15	4.450
20	5.930
25	7.410
30	8.900
35	10.380
40	11.860
45	13.350
50	14.830

*Ideal mechanical properties for maxillary and madibular bone. Cyclic rather than static loading on implants is of concern. Results for LBA above may need to be increased as much as 50% to achieve a clinical safety factor because of various bone densities. One pound of the patient's applied force requires 0.444 mm² of implant LBA to be in equilibrium in a compressive mode (not shear).

TABLE 2

Ideal occlusal force-to-bone density classification (occlusal force per tooth position in pounds per square inch (PSI)*



*FB_1 describes lamellar bone formation ideal for implants. FB_2, FB_3, and FB_4 indicate a decrease in bone quality, with an average variation of ± 10%. Note that the average force on molars doubles when compared with bicuspids. This phenomena characteristically is due to the second-class lever in the molar region having a mechanical advantage greater than the applied force. From the bicuspid to the incisors, a third-class lever is a function inversely proportional in magnitude based on the inverse law hypothesis having a mechanical advantage less than the applied force.

by a sinusoidal screw implant design and its physiologic function, but also addresses the fundamental principles of force equilibrium and the relationship between implant design and bone as dictated by the laws of physics; that is, mechanical forces come in pairs (*ie,* an applied force and a resisting force, which are equal in magnitude, opposite in direction, and collinear [Newton's Law]).

It is proposed that by studying ideal bone density (resisting force; Table 1) relevant to the range of forces generated in a specific implant region in the mouth (applied force), we can introduce an occlusal force to bone density classification for successful long-term implant selection (Table 2).

In the past, with early implant loading the science of implant design and its relationship to bone architecture and masticatory function was not as well understood. Success rates were relatively high considering the materials interface and early implant designs employed.[1,2] As the field evolved and submerged implant techniques were utilized, design and function were recognized as the determining factors for implant success. The benefits of implant prosthetic reconstruction became the widely accepted treatment modality with the concept of osseointegrated implants for missing teeth.[3]

BONE PHYSIOLOGY AND BIOMECHANICS

The physiology of bone under the control of mineral homeostasis involves both physiochemical and biological processes. Calcium, magnesium, and phosphate ions in specific concentrations are essential for osseous equilibrium and for ideal bone quality. Of these, calcium is probably the most important element. The concentrations of these ions should remain constant in extracellular and intracellular fluids and within the bone crystals as the cycle of bone resorption and remodeling continues.[4] However, physiologic conditions and bone architecture are not always ideal, and the need to stimulate osseous sites by implant design is proposed.

Biomechanically, bone is reported to be 65% weaker when tested under shear versus compressive loading.[5] The relevance and understanding of bone quality in various jaw regions became a paramount study, and the need for multiple implant designs capable of supporting the range of forces generated in these different occlusal force to bone density regions of the jaw supplied the determining guidelines for implant design.[6–8] Improving the implant's design by increasing the implant's load bearing areas (LBAs) as the primary functional mechanism to achieve osteocompression and support in the bone has been proposed as the primary factor in immediate-load implant success.[9] Implant dentistry has evolved to the beginning with immediate-load implants and the increase in

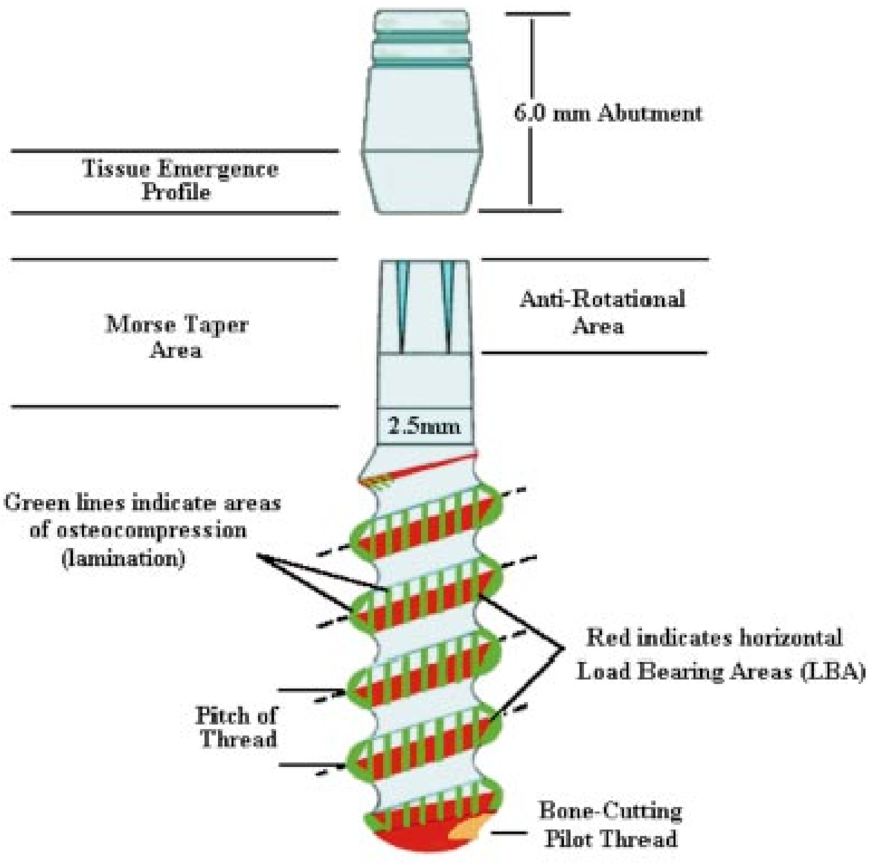


FIGURE 1. The lower portion of each thread, noted in red, is the horizontal load-bearing area (LBA), which sustains implant to bone equilibrium under function. Green areas indicate osteocompression/bone lamination by a functional profile of a sinusoidal screw thread design.

LBAs as the primary funtional mechanism for implant success (Fig 1).

Initially, it was the realization that if the horizontal supportive planes of an implant design are increased, it is possible for that device to function in controlled physiologic equilibrium based on the applied and resisting forces generated on a specific region of the jaw. The premise that increasing the horizontal planes of an unknown implant geometry will yield osseous equilibrium under a specific load will require a study to quantify and determine implant support values relevant to ideal bone architecture and force magnitude for a specific region of the jaw. Contractual research conducted at the George L. Schultz Laboratories for Orthopedic Research calculated the necessary amount of metal to ideal bone support required to achieve equilibrium under static loading. It was also determined that the amount of implant metal to bone support required (in millimeters squared) is less for the mandible when compared with maxillary bone in vertical compression (Table 1).[9–11]

These findings led to animal trials and clinical studies to confirm that an increase of LBA by this implant design, which bears as much as 95% of all masticatory forces by its horizontal planes, is an important mechanism for implant success.[12]

Conversely, insufficient LBA may explain the presence of fibrous tissue encapsulation at implant interface and the loss of crestal bone height for functioning dental implants under cyclic loading.[2,13,14]

In the late 19th century, Julius Wolff, an anatomist, published his hypothetical concept that ''bone develops the structure most suited to resist forces acting upon it''; in other words, bone models and remodels to adapt to the forces placed on it.[15] His classic law of bone remodeling incorporated two concepts: first, that the trabecular architecture of bone is adjusted to best withstand the prevailing loads, and second, that the mass of bone develops appropriately to the magnitude of the currently applied loads.[16,17]

It was thought that strain-related potentials (SRPs) were produced by piezoelectricity. It is also well known that electrical potential excites bone cells and influences the regenerative osseous capacity.[18–20] We also know physiologically acceptable stresses in bone, such as controlled functional compressive forces resulting in osseous strains (bone deformation or compaction within physiologic acceptable limits) induce SRPs, which will signal bone cells to deposit an extracellular matrix if ideal magnitude of force and direction is applied. Recent studies confirmed that SRPs are more specifically related to streaming potentials. Streaming potentials of osseous compression within physiologic limits generate extracellular fluid to flow over positively charged cell surfaces of the osteoblasts.[21] This creates a streaming electrochemical potential that stimulates osteogenesis.[22,23]

The relationship between metal implant design and limited bone trabeculation in a specific jaw region may not always be in equilibrium, especially under cyclic loading on a long-term basis through an inferior implant design that is not fully osseointegrated (Fig 2).[24]

Controlling force transfer to the osseous tissue through implant design is imperative since bone and metal have dissimilar moduli of elasticity, different mechanical properties, and their inter-

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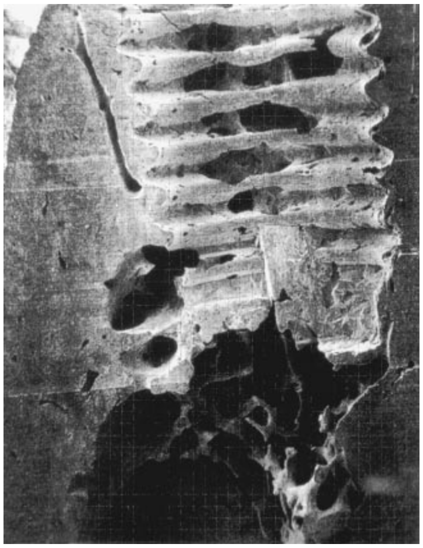

FIGURE 2. Scanning electron micrograph showing osseointegration by a Brånemark implant. Large trabecular spaces may circumvent as much as 55% of implant interface.

TABLE 3

LaminOss implant-bone interface*

	Total Surface Length (μ)	Bone Contact Length (μ)	Fiber Contact Length (μ)	% of Bone Contact	% of Fiber Contact
3 days unloaded	115,805.4	10,811.6	104,993.8	9.3	90.7
3 months unloaded	56,082.6	11,990.0	44,092.6	21.4	78.6
3 months loaded	41,002.6	18,775.5	22,227.1	45.8	54.2

*Results of light microscopy and an OS-2 image analyzer. No downward migration of epithelium was seen approximating the titanium implant body because of the use of OsteoGen. More osteoblastic activity/bone deposition was evident, which indicated a positive influence by the immediate-load sinusoidal implant thread design.

TABLE 4

LaminOss immediate-load implants: load-bearing areas and total surface areas*

Implant Length	9.0 mm	11.0 mm	13.0 mm	15.0 mm
3.3 mm Implant Diameter (Area in mm^2)				
Load-bearing area (LBA)	57.2	69.5	81.7	94.0
Total surface area (TSA)	105.2	129.7	154.2	178.8
	Passive thread for dense bone regions FB_2 and FB_3			
4.0 mm Implant Diameter (Area in mm^2)				
Load-bearing area (LBA)	68.0	82.2	96.4	110.6
Total surface area (TSA)	122.0	150.5	178.9	207.4
	Aggressive thread for spongy bone regions FB_3 and FB_4			

*Note the similar support values of LBA provided by a 3.3 × 13 mm implant compared with a 4.0 × 11 mm–long implant.

facial relationship is devoid of a physiologic attachment mechanism (Sharpey's fibers). Therefore, the magnitude of force to bone architecture can be in equilibrium through an implant design having increased horizontal planes of support (LBA) that are equal in magnitude, opposite in direction, and collinear in nature.

With natural dentition, the mechanism for bone stimulation is well known. The horizontal attachment of Sharpey's fibers from tooth root to osseous environment plays an important role in stimulating the bone and channeling nourishment. When force is applied on the tooth, the downward movement stretches the fibers. This pulling action causes tension in the bone, resulting in osseous stimulation. A vertical implant interface does not possess this biologic attachment mechanism for bone stimulation. Tension is caused by pulling on the tooth, and the attachment must be biologic—not mechanical.[25] Due to the lack of biologic attachment, the implant design must stimulate bone by compression since an insignificant amount of bone can be stimulated in tension by the implant model.

The areas of an implant's surface capable of providing maximum bone support and stimulation are the horizontal compressive planes, not the vertical implant interface under shear force. Furthermore, if the horizontal planes, or LBA, of an implant's geometry are not significant enough to sustain the forces generated in a specific bone region, a fibro-osseous condition may ensue. Progressive development of connective tissue, under cyclic loading, will eventually result in implant failure. To alleviate this fibro-osseous condition, increasing the load-bearing capacity of implant design[9] and enlarging the distance between implant threads (pitch) and decreasing minor diameters to improve immediate implant stability and support[10] have been proposed. Such improvement will increase osseous bulk density or bulk modulus, especially in a FB_4 bone architecture.[26]

THE LAMINOSS IMPLANT SYSTEM

From the patient's perspective, the healing period of 4 to 6 months recommended for a submerged one-stage or two-stage conventional implant design has long been a negative aspect of implant treatment. For the restoring doctor and the patient, the long waiting period before prosthetic reconstruction is an inconvenience and can be emotionally taxing. The use of implants having the benefit of increased LBA and the capacity for immediate loading provide a great advantage for the patient, the surgeon, and the restorative doctor. With the new osteocompressive immediate-load implant design, conventional crown and bridge restoration can begin following soft-tissue healing. Animal, laboratory, and clinical case studies over the past 10 years have indicated that the LaminOss one-piece and two-piece endosseous, titanium alloy implant designs can be loaded immediately following surgery. Animal histology of the LaminOss implant, conducted at Louisiana State University by Block and Meffert, supports the principle of controlled functional osteocompression and the benefit of streaming potentials to be functions of the LaminOss implant design. At 3 months, immediately loaded LaminOss implants exhibited more than twice the amount of bone density at implant interface when compared with unloaded controls of the same design (Table 3).

Histologically, none of the eight implants, loaded or unloaded, showed any evidence of bone necrosis in the area of direct bone lamination at implant interface at the 3-day or 3-month intervals. Implant sites that were countersunk crestally received a synthetic bioactive resorbable graft (SBRG; OsteoGen, Impladent) to prevent the downward migration of the epithelium and restore osseous residual defect sites (Fig 3).[12]

Studies were contracted with Polytechnic University, Brooklyn, NY, for analysis of the total surface area and LBA for each implant design of the LaminOss. Results have confirmed that the LaminOss implant utilizes a technologically advanced, round-thread design, known as a sinusoidal screw thread profile with a hemispherical apex. This thread design provides maximum load bearing areas that, when coupled with unique sequential surgical instrumentation, achieves maximum viable bone interface by osteocompression. This device, compared with other implant studies, has the capacity to improve distribution of stresses at implant interface as well as reduce concentration of excessive coronal and apical stresses due to the increase of horizontal LBA (Table 4).[10,13,14] In an osteopenic maxilla, the LaminOss two-piece implant may also be indicated for a one- or two-stage surgical procedure by grafting the implant and osteotomy and loading it 4 months later. This grafting, or ''force-mineralization technique,'' can effectively be accomplished using a material that has the same chemical and mechanical properties as the host bone (*ie,* SBRG) to fill the marrow spacings and fatty cells, thus providing initial foundation for implant stability as the material resorbs and new bone formation occurs (Fig 4).[27–29]

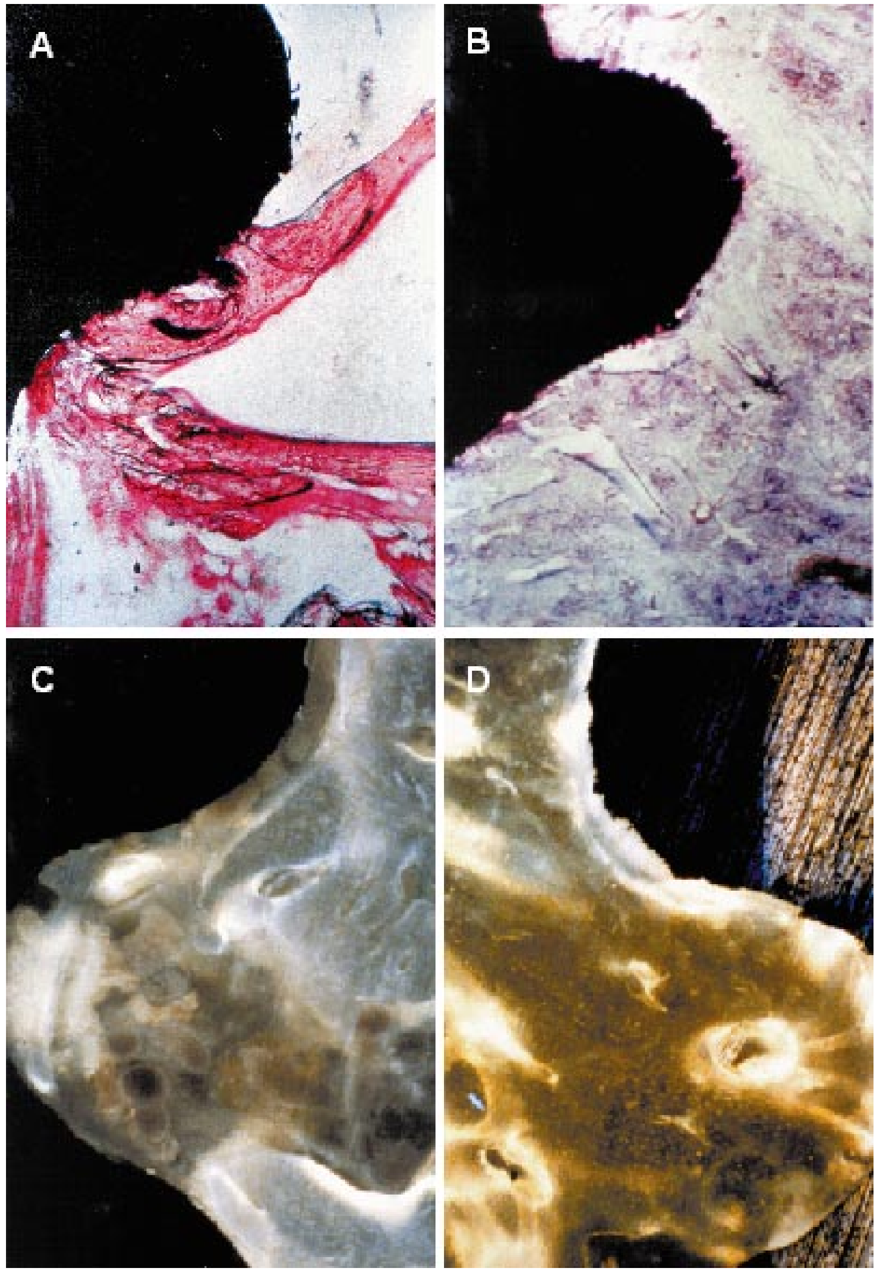

FIGURE 3. (A) Three-day specimen (unloaded). Note minimal amount of bone/implant contact with large trabecular spacing. Black area indicates implant threads (×50). (B) Three-month specimen (loaded). Good bone/implant contact with an insignificant amount of trabecular spaces and increased bone density by 2.5 times due to osteocompression (×50). (C) Three-month specimen (unloaded). Note sparse fluorescence of bone/implant interface (×50). (D) Three-month specimen (loaded). Dense bone with increased fluorescence indicating increased bone activity as a result of the principle of osteocompression and the action of streaming potentials by a sinusoidal implant design (×50).

The minor diameter of all sinusoidal functional-profile thread designs is approximately 2.5 mm, including implant neck. This feature will not compromise vascularity buccal lingually at the crest of the ridge. The outer diameter of the aggressive thread, designed for spongy bone, is approximately 4 mm. The diameter of the less aggressive thread is 3.3 mm, with an approximate thread pitch of 1.3 mm used for denser bone (FB_1). A 3.3-mm implant with an aggressive thread pitch of 2 mm (*ie,* 4 mm diameter implant) is also provided for a narrow ridge with spongy trabecular structure. (Note: the surgical protocol for spongy trabecular bone requires undersizing the osteotomy by as much as 25% in diameter and length. In most instances, countersinking the thick cortex will be required.) All threads are designed for maximum LBA to sustain muscular forces by the elevator muscle and maintain equilibrium on a long-term basis. It is recommended that the LaminOss implants be selected for a specific region of the jaw based on occlusal force to bone density classification by three factors (region of bone density, force magnitude, and implant LBA) to attain equilibrium as described in Table 2 and Table 5. Since a force is an action, it is always opposed by an equal reaction. Therefore, forces exist not singly, but always in pairs (Newton's third law).

As immediate-load one-piece and two-piece implants, the LaminOss system uses the precision surgical osteotomy in conjunction with specific implant geometries and MicroPores implant surface technology to achieve Controlled Functional Osteocompression (Fig 5).

Following surgery, implants must be splinted to each other and/or connected to natural abutments to prevent counterrotation (due to osteocompression) and to achieve osseointegration. For single-tooth replacement, broad mesiodistal contacts are recommended to prevent counterrotation with well-balanced occlusion. Provisional acrylic bridges are used as guide stents for implant placement and alignment, as well as immediate temporary prostheses that should not be removed during initial bone healing.[7]

Regardless of an implant's design, the osseous interface immediately following surgery can be classified as woven bone. Woven bone has relatively low mineral content and randomly oriented fibers providing minimal sup-

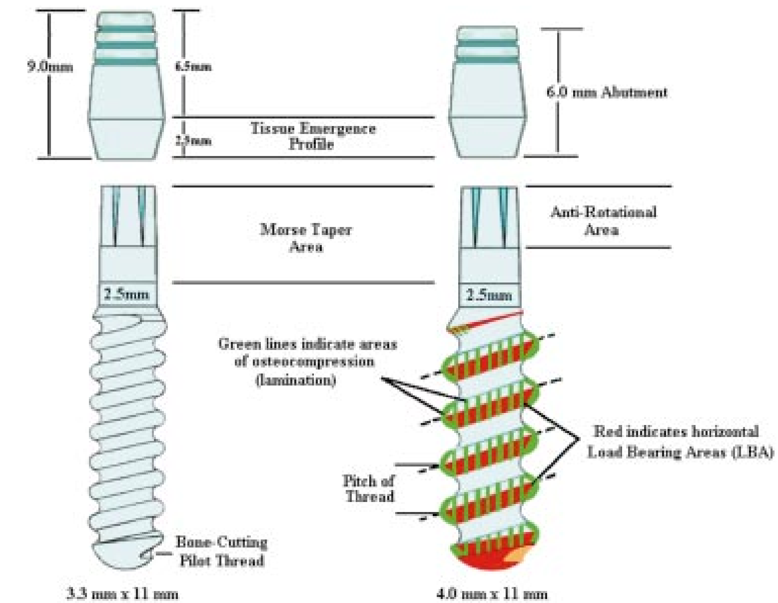

FIGURE 4. Note the different thread design. The larger pitch is designed as an aggressive thread having greater load-bearing areas for spongy bone, as noted in occlusal force to bone classification (*ie,* FB_4; Table 2).

TABLE 5

LaminOss implant selection guide based on load-bearing area (LBA) and occlusal force-to-bone density classification*

Implant Length (mm)	Force-to-bone Region	Implant Placement Region	Implant Load-bearing Area (mm^2)
9	FB_1	Anteriors	57–68
11	FB_2	Upper and lower bicuspids	69–82
13	FB_3	Lower molars	82–96
15	FB_4	Upper molars	94–110

*A range of implant LBA is given according to the implant length most suitable for long-term success. Note that a 9 mm implant length is not recommended for the maxillary molar region. It is suggested that a minimum of one implant having LBA greater than 80 mm^2 (with an average variation of $\pm$10%) be placed per tooth in the molar region.

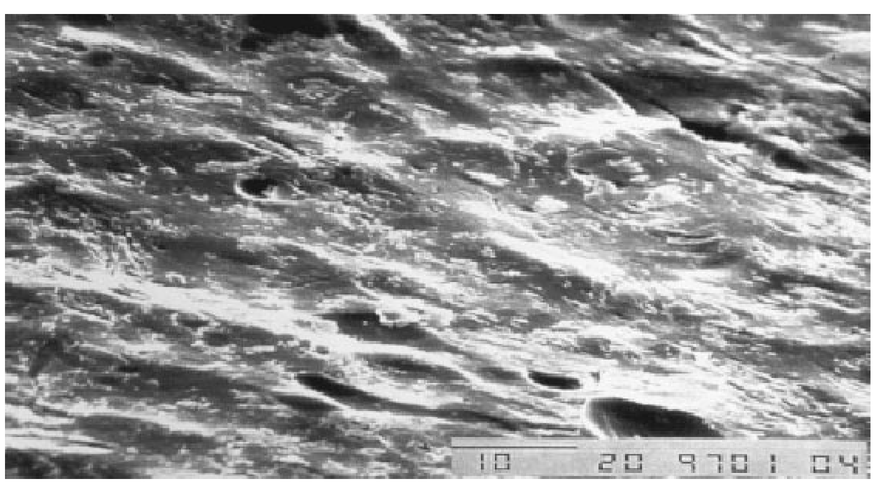

FIGURE 5. Scanning electron micrograph of MicroPores implant interface. Surface may be blasted with hydroxylapatite and chemically milled for greater cell adhesion.

port or strength.[30] However, the osteocompressive action of the LaminOss compacts and densifies bone at the interface, providing greater initial stability.[12] Surgical preparation of the implant osteotomy is simplified by appropriate armamentarium used sequentially as prescribed in the protocol for each of the LaminOss implant systems.[7] Bioactive resorbable, synthetic bone grafting techniques, as mentioned above, may be considered to ''force-mineralize'' osteotomies inferiorly and superiorly (especially in FB_4 bone density regions; Table 2) and place implants out of function.[31,32]

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