Short Dental Implants

A Literature Review and Rationale for Use

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When treatment planning for dental implants, the height of available bone is often used to determine the implant length, if adequate width and mesio-distal space are present. The height of available bone is measured from the crest of the edentulous ridge to the opposing landmark. The posterior regions of the jaws usually have the least height of existing bone, since the maxillary sinus expands after tooth loss and the mandibular canal is 10 mm or more above the inferior border of the mandibular body.[1] A radiographic study of 431 partially edentulous patients revealed that the posterior placement of implants at least 6 mm in length was possible in only 38% of maxillae and 50% of mandibles.[2] The posterior regions of the mouth have a higher bite force than the anterior regions[3] (Figure 1). As a consequence, in the posterior regions of the mouth with the highest bite forces, the existing available bone for implants is often less compared to anterior edentulous sites.

A review of the literature reveals implants shorter than 10 mm often have a higher failure rate than longer implants. These complications may be related to an increase in crown height, higher bite forces in the posterior regions, and less bone density.

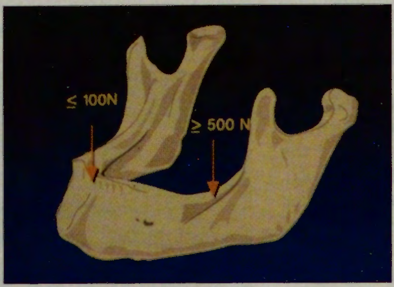


Figure 1. The posterior regions of the mouth have higher bite forces than the anterior regions. The available bone height is usually less in the posterior than the anterior sections.

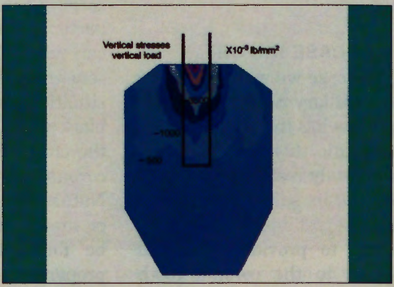


Figure 2. A 3-D model of an implant in bone demonstrates the highest strain applied to the bone area in the crestal 5 mm of the implant body.

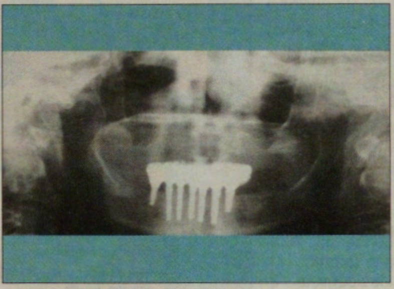


Figure 3. Radiograph of 2 BioHorizons 9-mm implants in the posterior mandible that are connected to longer implants in the anterior mandible.

Figure 4. The fixed, full, 5-arch restoration of Figure 3 is supported by 7 BioHorizons dental implants.

RATIONALE FOR SHORT IMPLANT LENGTH

Stresses distributed to the apical third of an implant are of much less magnitude than those in the crestal third. Most endosteal dental implants are fabricated from alloyed or pure titanium with a modulus of elasticity (stiffness) approximately 5 times greater than dense cortical bone.[4] A basic mechanical principle states that when 2 materials of different moduli are placed together with no intervening material and one is loaded, a stress concentration can be observed where the 2 materials first come into contact.[5] These stress contours form a v-shaped or u-shaped pattern, with greater magnitude near the point of first contact, which corresponds to the crest of the bone.[6] For an implant in bone of adequate density with a direct bone contact, the greatest magnitude of stress is concentrated in the crestal 5 mm of the bone-implant interface. The phenomenon of higher crestal stresses next to an implant is confirmed in photoelastic and 2-D or 3-D finite element analysis (FEA) studies when an implant is placed within a bone simulant and loaded[7,8] (Figure 2). Therefore, although implant length does affect the overall surface area of an implant support system and is therefore theoretically desirable, stresses around implants during function and parafunction are typically concentrated at the crest of the ridge, unlike what occurs for a natural tooth and its periodontal membrane.

There are many advantages to using short dental implants to support an implant prosthesis. Bone grafting to compensate for the expansion of the sinus and/or loss of available bone height at the crest is unnecessary prior to implant placement. This saves the patient time and money and eliminates the pain related to the procedures. Shorter implants are easier to insert. Osteotomy preparation is simplified. The potential for overheating the bone is less, since the bone preparation is in a short site and the irrigation has direct access. Angulation to the load may be improved, since the basal bone beyond the original alveolar ridge for longer implants is not always in the long axis of the missing tooth (Table 1).

A question that is very relevant to implant treatment planning is this: at what length does an implant begin to have an increase in complications? The purpose of this article is to review the literature related to implant length and implant survival. In addition, the biomechanical issues related to implants of 10 mm or less will be addressed, including guidelines to reduce risks of failure.

LITERATURE REVIEW

A *Medline* search of 13 studies related to implant failure and implant length was published by Goodacre, et al[9] in 2003.[10-22] In these reports 2,754 implants were 10 mm or less in length, and 3,015 implants were greater than 10 mm in

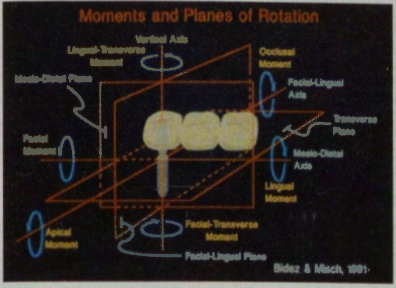
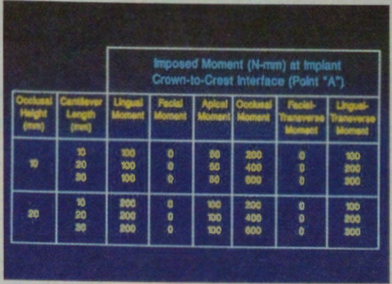


Figure 5. When a cantilever force is applied to an implant, 6 different rotation points (moments) are created around the implant.



Occlusal Height (mm)	Cantilever Length (mm)	Imposed Moment (N-mm) at Implant Crown-to-Crest Interface (Point "A") Lingual Moment	Facial Moment	Apical Moment	Occlusal Moment	Facial-Transverse Moment	Lingual-Transverse Moment
10	10	100	0	50	200	0	100
	20	100	0	50	400	0	200
	30	100	0	50	600	0	300
20	10	200	0	100	200	0	100
	20	200	0	100	400	0	200
	30	200	0	100	600	0	300

Figure 6. When the crown height is increased from 10 mm to 20 mm, the lingual moment and apical moment are increased 200%.

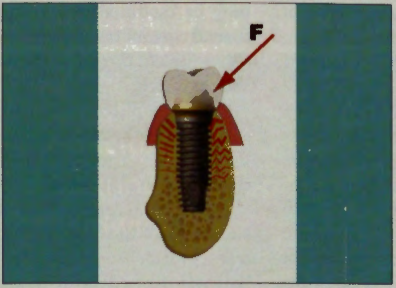


Figure 7. An angled force to an implant crown increases the amount of force applied to the bone, and an angle of 12° increases the force by 20%. When this angle is applied to a crown height of 15 mm with 100 N of force, the force is magnified to 315 N-mm.

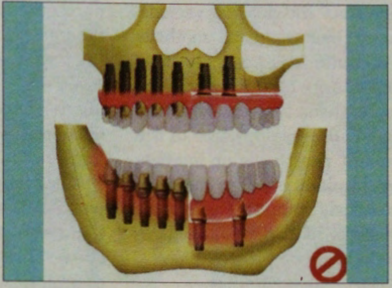


Figure 8. When the number of implants is related to the height of bone, less bone height (and greater crown height) receives fewer implants. The biomechanics increase the stress when increased crown height and reduced implant areas are used to support the prosthesis.

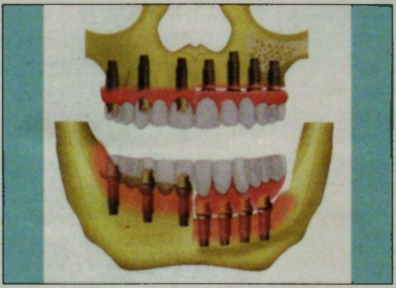


Figure 9. When the crown height increases, the cantilever length should be reduced and the implant number should be increased.

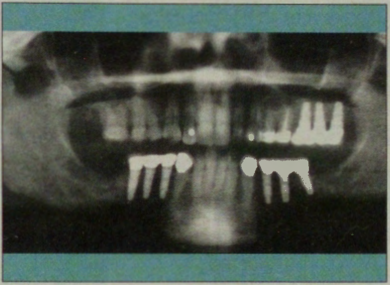


Figure 10. Splinted implants are especially important in the posterior regions of higher stresses and/or poorer bone density. This panoramic film demonstrates an increase in implant number in the posterior maxilla with short, 9-mm implants in poor bone density. The implants are splinted together in both arches.

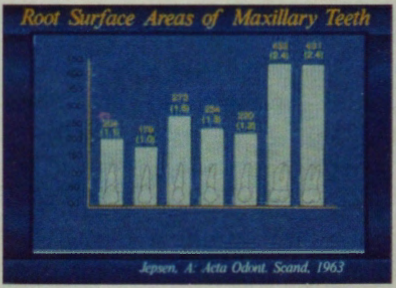


Figure 11. The natural teeth increase surface area by 200% in the molar region. This reflects the increase in force at this position in the arch.

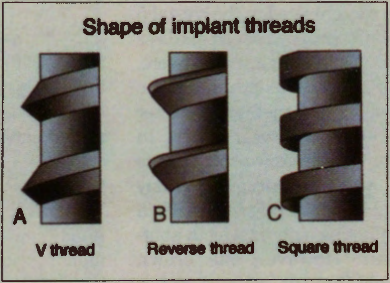


Figure 12. The thread shape of an implant body may be v-shape, reverse buttress, or square.

length. The failure rate of implants 10 mm or less was 10%, compared to a 3% failure rate of implants longer than 10 mm.

In addition to the Goodacre, et al[9] review, several other papers have reported clinical results with screw-type dental implants of reduced length. Minsk, et al[23] reported the results of a training center in 1996, with 80 different operators using 6 different systems over a 6-year period. Implants 7 mm to 9 mm in length reported a 16% failure rate. The overall survival rate of all lengths was 91.3%. Hence, similar to the Goodacre, et al[9] review, shorter implants had at least a 7% higher failure rate when they were less than 10 mm long.

Ivanoff, et al[24] in 1999 found an 8-mm-long, 5-mm-diameter implant failed 25% of the time in the maxilla and 33% of the time in the mandible. On the other hand, the 10-mm and 12-mm implants that were 5 mm in diameter reported no mandibular failure and a 10% failure in the maxilla.

Winkler, et al[25] published a multicenter report in 2000. These data were collected from more than 30 hospitals and 2 university sites during a 3-year period and represented 6 different implant body types. The 7-mm-long implants had a 25.6% failure rate, while 16-mm implants demonstrated only a 2.8% rate of failure. Implants of 8 mm had a 13% failure rate, while 10-mm implants failed at a rate of 10.9% and 13-mm implants failed at a rate of 5.7% within the 3-year period reported. Therefore, failure rate was directly related to implant length: it increased 2 to 5 times with shorter implants.

A multicenter study of 6 different centers was reported by Weng, et al[26] in 2002 and found 60% of all failed implants were 10 mm or less in length. The overall failure rate of all implants in the study was 9%. The 7-mm implant failed 26% of the time, the 8-mm implant had a 19% failure, while the 10-mm implant had a 9% failure. Therefore, the 10-mm implant survival was more similar to the longer length implants, while implants shorter than 10 mm demonstrated significantly greater risks of failure.

Naert, et al[27] also reported on clinical outcomes of dental implants in 2002. They found a cumulative survival rate of 91.4%. Implants shorter than 10 mm had a survival rate average of 81.5%. Therefore, these additional reports agree with the Goodacre, et al[9] summary of articles that indicates failure rates are higher in implants of shorter length. However, many of these clinical findings are more alarming, since implants shorter than 10 mm had a risk of failure of 16% to 33% versus a failure rate of 4% to 9% for longer implants.

It should be noted that the failure rates in these reports are not surgical failures or failures to osseointegrate. The failures reported occurred after prosthesis delivery and prosthetic loading. In other words, the surgical success did not vary relative to implant length, but once the prosthesis was loaded, an increase in failure was observed, especially within the first 2 years.

On the other hand, a retrospective report by Misch, et al[28] was compiled from 2 private offices using a square thread implant body design (BioHorizons) rather than a v-shaped thread as primarily reported in the previous literature. During a 3-year period, 126 patients received implants less than 10 mm long. The total number of implants in this report was 437 (408 implants, 9 mm long and 29 implants, 7 mm long), which supported 141 restorations. The majority of these restorations were in the posterior mandible or maxilla. The restorations in this report were loaded for at least 18 months.

Of the 437 implants, there were 3 implant failures in the posterior mandible and 1 failure in the posterior maxilla (99% survival). All these failures were implants 9 mm long and 4 mm in diameter. No implants failed during the prosthesis fabrication. Hence, the overall implant survival from stage 1 surgery to prosthesis delivery was 99.0%. The implants and restorations were followed at least 18 months and as long as 3 years. No implants were lost during this time frame, and no restorations were refabricated (Figures 3 and 4).

This report used several guidelines for treatment in the use of short implants: a change in implant design, splinting implants together, no cantilevers in the prosthesis, and additional methods to decrease stress to the implant interface. Hence, from this clinical report, these modifications of treatment may decrease the risk of failure with shorter implant lengths (Table 2).

DISCUSSION

The loading failure of short implants may be due to a number of factors, including an increase in forces from an increased crown height. As the crestal height of the ridge is resorbed, the available bone height is reduced and the crown height is increased. When an osteoplasty is used to increase the width of crestal bone for implant insertion, the available bone height is reduced and the crown height is increased. As a

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Table 1. Advantages of Short Implants.

(1) Bone grafting for height often unnecessary.
(2) Less money, pain, and time prior to restoration of the implant.
(3) Short implant bone surgery simplified.
(4) Implant insertion easier.
(5) Angulation to load may be improved.

Table 2. Short Implant Failure Rates.

Author	Failure Short Versus Long
Goodacre, et al[9] (13 articles)[10-22]	10% versus 3%
Minsk, et al[23]	16% versus 9%
Ivanoff, et al[24]	30% versus 5%
Winkler, et al[25]	25% versus 3%
Weng, et al[26]	26% versus 9%
Naert, et al[27]	19% versus 8%
Misch, et al[28]	1% versus 1%

consequence, limited length endosteal implants are often used when the crown height is greater than ideal.

Force magnifiers are situations or devices that increase the amount of force applied and include a screw, pulley, incline plane, and a lever. The biomechanics of the crown height are related to lever mechanics. The issues of lever mechanics were first observed in implant dentistry for fixed prostheses with posterior cantilevers in edentulous patients. The length of the posterior cantilever was directly related to complications with and/or failure of the prosthesis.

When the forces to the implant are applied on a cantilever, they are magnified in direct relationship to the height of the crown. In other words, the crown height becomes a vertical cantilever. Bidez and Misch[29] evaluated the effect of a cantilever on an implant and its relation to crown height. When a cantilever is placed on an implant, there are 6 different potential rotation points (ie, moments) on the implant body (Figure 5). When the crown height is increased from 10 mm to 20 mm, 2 out of 6 of these moments are increased 200% (Figure 6). The consequences of excessive crown height may be limited when cantilevers are eliminated in the restorations. Therefore, 2 important implant positions are at each of the terminal ends of the prosthesis.

An angled load to a crown will also magnify the force to the implant.[30] When an implant is inserted at an angle of 12° to the occlusal force direction, the force to the implant will increase by 20% (Figure 7). This increase in force is further magnified by the crown height. For example, a 100-N force with a 12° angle will result in a 315-N-mm force on a crown height of 15 mm. As a consequence, when posterior implants are placed for fixed prostheses, incisal guidance on the anterior teeth is warranted. The elimination of lateral forces during mandibular excursions is especially beneficial to decrease the effects of an increased crown height.

Since an increase in the biomechanical forces are in direct relationship to the increase in crown height, the treatment plan for the implant restoration should consider stress-reducing options whenever the crown height is increased.

Bone Density

The density of the bone is directly related to the strength of the bone. Softer bone types are 50% to 80% weaker than denser bone qualities. On average, implants loaded in soft bone have a 16% higher failure rate. Several reports in the posterior maxilla report 25% failure when short implants are used to support the prosthesis. The posterior regions of the jaws often have less dense bone than the anterior regions. Hence, biomechanical methods to decrease the stresses to short implants are further warranted.

Methods to decrease stress include decreasing force to the implant prosthesis or increasing implant surface area of prosthesis support. These modifications of treatment include the following:[30]

Decreasing Force:

(1) Decrease lateral forces to the posterior implant prosthesis (incisal guidance).

(2) Eliminate cantilevers in the restoration.

Increasing Implant Surface Area:

(1) Increase the number of implants.

(2) Splint the implants together.

(3) Increase the diameters of implants.

(4) Increase the surface area design of implants:

- thread number.
- thread depth.
- thread shape.

Implant Number

Most forces applied to the osteointegrated implant body are concentrated in the crestal 5 to 7 mm in good bone, regardless of implant design.[4-7] Therefore, implant body length is not the most effective method to counter the effect of crown height. In other words, crown-root ratio is a prosthetic concept that may guide the restoring dentist when evaluating a natural tooth abutment. However, the crown height-implant ratio is not a direct comparison. Rather than increasing the implant length, the risks of greater crown height and/or less bone density may be reduced by increasing the number of implants usually required for the prosthesis, especially in the presence of other force factors. This is a complete paradigm shift from the concepts advocated originally with many implants in greater available bone with small crown heights, and fewer implants with greater crown heights in atrophied bone (Figures 8 and 9).

Splinted Implants

In order to benefit from the increased number of implants, the crowns should be splinted together. The splinted crowns decrease the force to the prosthesis, the cement, the abutment screws, and the implant-bone interface compared to unsplinted restorations. In order to benefit maximally from an increased number and/or surface area of the implant by width or design, the implants should be splinted together. Splinted implants increase functional surface area of support wherever the load is applied to the prosthesis. Splinted implants may also compensate for less bone density (Figure 10). Individual implants/crowns increase the stress to each implant prosthetic unit, including porcelain on the crowns, cement interface, abutment screws, and the bone-implant interface.

The aesthetics of the prosthesis is rarely improved by individual crowns, especially in the posterior regions. The hygiene of the implants may be easier in terms of flossing with individual crowns, but only 10% to 20% of patients floss.[31] The other 80% to 90% of the patients would receive no hygiene benefit. Yet all of these patients have an increased stress risk factor and may lose their implants as a result. Rarely is implant loss due to a lack of using dental floss in comparison to overload of the restoration.

Implant Size

Methods to increase the functional surface area, specifically in the crestal 5 to 7 mm, is warranted, especially in the posterior regions that have greater forces applied to the prosthesis. The logical method to increase functional surface area by implant design is by increasing the diameter of the implant. For every 1-mm increase in diameter, implants may increase the functional surface area by 30% to 200%, depending on their design (ie, cylinder versus square thread shaped implants).[32] This is most important in the molar region, where the surface area of the natural tooth increases 200% (Figure 11). When larger diameter implants cannot be used, 2 implants for each molar are suggested. However, the report by Ivanoff, et al may indicate that implant diameter is not the only factor to increase success of a short implant, since a failure rate of 25% to 33% still was observed in the posterior regions with short implants.[24]

Implant Design

(1) *Thread Pitch.* Functional surface area is that portion of an implant interface that is able to transmit compressive or tensile loads to the bone.[33] It may be modified by varying 3 thread geometry parameters: *thread pitch, thread shape*, and *thread depth*.

Thread pitch is defined as the distance between adjacent threads or the number of threads per unit length in the same axial plane and on the same side of the axis. Restated, a decrease in the distance between threads will increase the number of threads per unit length. For example, the distance between the threads for certain implants is 1.5 mm, whereas the most common thread distance is 0.60 mm. One implant has a thread distance of 0.4 mm. The greater the number of threads, the greater the surface area, if all other factors are equal.

(2) *Thread Depth.* The thread depth refers to the distance between the major and minor diameter of the thread.[32] The greater the thread depth, the greater the surface area. Not all implants have the same depth of thread. One implant design may have a thread depth of 0.28 mm, whereas others have a thread depth of 0.419 mm.[32] The latter thread depth results in greater functional surface area.

(3) *Thread Shape.* The thread shape is another characteristic of overall thread geometry. Three thread shapes presently represented in dental implant designs include: square, v-shape, and a reverse buttress (Figure 12). In conventional engineering applications, the v-thread design is called a "fixture" and is often used for the fixation of metal parts. This thread shape is the most commonly used for fixing the abutment screws to the implant body and is the most common thread shape. The reverse buttress thread shape is similar, but flat on the top, which is optimized for pullout loads. This thread design origi-

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nated from a German engineer (Krupp) and was used to prevent screws from pulling out of concrete bunkers used to hold artillery cannon during World War I.[32] The square or power thread provides more surface area for intrusive, compressive load transmission.[33]

An animal study by Steigenga, et al compared these 3 thread types with identical surface condition, thread number, and thread depth.[34] The v-shape and reverse buttress thread types had similar bone-implant contact percentage and similar reverse torque values to remove the implant. The square thread design had a higher bone-implant contact percent and a greater reverse torque test value. Hence, it appears that thread shape may also be an important parameter in an implant design.

SUMMARY

Implant prostheses are often used to restore partially or completely edentulous patients. The posterior regions of the mouth often have less available bone height than the anterior regions. The bone density of the remaining bone after tooth loss is often less in the posterior regions than the anterior region of the mouth.

A review of the literature reveals implants shorter than 10 mm often have a higher failure rate than longer implants. These complications may be related to an increase in crown height, higher bite forces in the posterior regions, and less bone density. As a result, biomechanical methods to decrease stresses to the implant-bone interface are warranted.

The forces to the implants may be reduced by eliminating lateral contacts in mandibular excursions and eliminating cantilevers on the prosthesis. The area of forces applied to the prosthesis may be increased by increasing the implant number, increasing the implant diameter, increasing the implant design surface area, and splinting the implants together. As a result of these biomechanical methods to decrease stress, Misch, et al reported a 99% implant survival with 7-mm and 9-mm implants in the posterior regions of the jaws.[28]

It is interesting to note that the natural teeth follow a similar biomechanical approach to accommodate the higher bite forces in the posterior regions of the mouth. The molar teeth do not become longer than the anterior teeth. The diameter is increased, the design of the roots is different, and the roots are splinted together. The anterior teeth have incisal guidance and eliminate posterior lateral forces to the posterior teeth in all mandibular excursions. A similar biomechanical approach is logical for posterior implants, especially when shorter implants are used to support the prosthesis.✦

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Disclosure: Dr. Misch is co-inventor of the BioHorizons Dental Implant System, is a paid consultant of BioHorizons, and is also on the board of directors.

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