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Original Article

Innovations in Implant Dentistry: Exploring the Benefits of Short Implants

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ABSTRACT

The success of dental implants has led to an increased focus on methods to simplify the surgical procedure and increase implant longevity. With advancements in technology, the use of implants has expanded to include even the most complex cases. However, bone resorption following tooth extraction can lead to reduced bone volume and height, making standard implant placement challenging. In such situations, shorter implants have been suggested as an alternative, although their effectiveness as a treatment option remains unclear. Short implants offer advantages such as shorter treatment times, easier procedures, reduced patient morbidity, and lower costs. However, the literature also documents several biological complications, which could lead to their failure. This review examines the biomechanical factors, determinants of success, and the potential of short implants as a feasible solution for the rehabilitation of atrophic maxillary and mandibular alveolar ridges.

Keywords: Mandible, Dental implants, Short implants, Implantology, Maxilla.

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Introduction

Bone resorption following tooth extraction can significantly reduce both bone volume and height, making implant placement challenging [1]. After tooth loss, the posterior regions of the maxilla and mandible experience distinct patterns of bone loss. The maxilla typically shows slower vertical bone loss but experiences more significant horizontal loss in the buccal-palatal direction. This bone remodeling, along with maxillary sinus pneumatization, contributes to the vertical bone loss in 2 different directions. In contrast, vertical bone loss in the mandible mainly affects the vertical dimension, often reducing bone height but leaving a reasonable amount of horizontal bone. Planning for implant placement in atrophic posterior arches is particularly complex due to these bone loss patterns and the proximity to important anatomical structures. The maxillary sinus expansion and the position of the mandibular canal (which is generally 10 mm or more above the inferior border of the mandible) typically result in reduced bone height in the posterior regions of both jaws [2]. To address this, techniques like guided bone regeneration (GBR), block grafts, sinus augmentation, and distraction osteogenesis have been proposed to restore lost bone height before implant placement. While these procedures have been successful, they come with increased complexity, sensitivity, and risks. As an alternative, short implants—defined as implants less than 10 mm—offer a less invasive solution for such cases. These implants simplify the surgical and prosthetic procedures, making the treatment more accessible and cost-effective [1]. Key parameters to assess in such cases include marginal bone loss, implant survival rates, failure rates, and biological complications such as bleeding on probing and probing pocket depth [3]. Advances in implant surface geometry and texture have improved bone-to-implant contact, contributing to better primary stability during osseointegration. In cases of severely resorbed edentulous mandibles, six short implants may be used to support a fixed prosthesis, or 4 short implants may support an overdenture. In the edentulous maxilla, two additional short implants can be placed in the distal region alongside longer implants in the premaxilla to support a fixed prosthesis or overdenture [4]. This article aims to introduce the use of short implants in various clinical scenarios.

Results and Discussion

History

The development of the Bicon dental implant system in 1968 by Thomas Driskell marked a significant advancement in implant technology with the introduction of the 8-millimeter implant (**Figure 1**). Before this, the shortest conventional endosseous implants were 10 millimeters in length. Braunemark introduced the 7-millimeter implant, which led to the categorization of implants into two groups: short implants and ultra-short implants. “Short implants” are generally defined as those ranging from 7 millimeters to 10 millimeters in length, while “ultra-short implants” are those shorter than 7 millimeters. Additionally, the Bicon system introduced a 5-millimeter implant, which received approval from the Food and Drug Administration (FDA) in 2008 [5].

The Bicon system stands apart from other implant systems due to its unique design, largely influenced by Dr. Vincent J. Morgan, the founder and president of the company. Bicon believes that traditional threaded implants and high-speed drilling are unnecessary. Their system uses only three threads, which minimizes the risk of bone degeneration caused by heat and pressure, common issues with high-speed drilling. Driskell’s insight into the damage caused by fast drilling led him to adopt slow drilling methods in 1968. This approach offers numerous benefits, including greater patient comfort, the ability to harvest bone, improved visibility, and a significantly reduced risk of bone necrosis.

Figure 1. Bicon implant system

Short implants are highly effective because of the nature of the surrounding bone, which is primarily Haversian and cortical. These types of bone have superior mechanical properties compared to the appositional bone that surrounds traditional threaded implants. The effectiveness of an implant is largely influenced by its macro-geometry. For Bicon implants, the osteotomy is prepared using slow drilling at around 50 RPM, or slower with hand reamers. After the implant is inserted, the blood in its plateaus quickly transforms into Haversian bone, resembling cortical bone without osteoclastic activity. In contrast, when a threaded implant is inserted, pressure is applied to the bone, initiating osteoclastic activity [6].

While primary stability is an important factor, the first event following the insertion of a threaded implant is osteoclastic activity. The bone begins to regenerate as appositional bone, which lacks blood vessels, unlike the Haversian bone around short implants. This difference in bone characteristics may explain the higher success rate observed with short implants [7].

Thomas Driskell’s Bicon dental implant design, established over thirty years ago, has proven effective through numerous prosthetic restorations performed on this system [8].

Biomechanical Considerations

Implant Diameter

The bone crest receives the most stress during the implant process, while the apical section experiences significantly less stress. Increasing the length of an implant improves primary stability, but a wider diameter not only enhances primary stability but also increases the functional surface area at the bone crest, thereby improving the distribution of occlusal stresses. A finite element analysis by Himmlová *et al.* [9] demonstrated that a large implant diameter reduced stress around the implant neck and distributed masticatory forces more effectively. Similarly, Gavali *et al.* [10] reported that increasing implant length enhances surface area and primary stability by increasing bone-implant contact (BIC). However, the functional surface area (FSA), which transmits compressive and tensile stresses to the bone, is primarily confined to the crestal 5 to 7 millimeters. Therefore, increasing the implant length beyond this point doesn't alter the FSA. On the other hand, a shorter implant with a wider diameter offers improved primary stability and a larger FSA [10].

Crown-to-Implant Ratio

A molar tooth can remain functional for decades with minimal root support, as demonstrated by ankylosed teeth. Advances in implant surface technology and load distribution have enabled the successful use of high crown-to-implant ratios. Meijer et al. reviewed studies and found that the crown-to-implant ratio for nonsplinted single-tooth implants ranged from 0.86 to 2.14, showing a low occurrence of biological or technical complications [11, 12]. According to Da Rocha Ferreira *et al.* [13], factors such as implant diameter, micro and macro geometry, implant-abutment connection, and bone quality and volume play a role in marginal bone stress. They concluded that the primary cause of marginal bone stress is excessive prosthetic height. This suggests a paradigm shift where prosthetic height is prioritized over implant length or crown-to-implant ratios. Further research is needed to develop new prosthetic designs that minimize stress at the marginal bone level (**Figure 2**) [13].

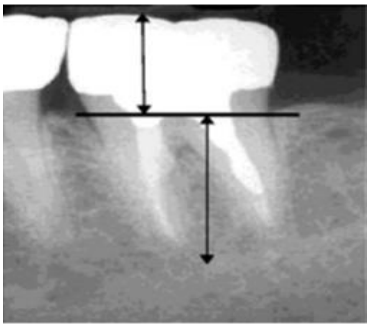


Figure 2. Crown-implant ratio

Bone Quality

The success of short implants is largely dependent on the quality of the jawbone and its composition [14]. Research by Maló *et al.* [15] found that short implants in the mandible, which generally contains type I and II bone, exhibited a 99% success rate, whereas implants in the maxilla, predominantly made up of type III and IV bone, had a lower success rate of 92%. The porous structure of the maxillary bone is believed to have contributed to the varying success rates and implant failures observed in these cases [15]. Galvão *et al.* [16] reviewed cases and noted that, regardless of the implant's surface treatment, failures were more frequent in areas with type III and IV bone, where bone density is lower. Short implants placed in regions with insufficient bone density may struggle with stability during both the initial placement and the healing period. Additionally, Liu *et al.* [17] found that in mandibles with inferior bone quality, surrounding bone in short implants was more prone to resorption. Tawil's patient series highlighted that the quality of bone plays a more significant role in determining implant longevity than the quantity of bone available (**Table 1**) [18].

Table 1. Bone density classification by Misch [19]

BONE	DENSITY	
D1	> 1250 HU	Dense cortical bone
D2	850-1250 HU	Thick dense to porous cortical bone on crest and coarse trabecular bone
D3	350-850 HU	Thin porous cortical bone on the crest and fine trabecular bone within
D4	150-350 HU	Fine trabecular bone
D5	< 150 HU	Immature, non- mineralised bone

Absence of Cantilevers

Cantilevers intensify the forces applied to the implant, with the force magnifying as the crown height increases. This creates multiple potential pivot points on the implant's body. By removing cantilevers, the predictability of treatment is improved, and biomechanics are enhanced [4, 19]. Thoma *et al.* [20] found that short implants without cantilevers produced radiological and comparable clinical outcomes to those with cantilevers after 5 years. However, the cantilevered implants tended to fail earlier, indicating they were subject to excessive force. Both options can be appropriate for clinical assessment [20].

Number of Implants

Increasing the number of implants improves the distribution of occlusal stresses by expanding the surface area that the implants can handle [4].

Implant Design

The thread design on the implant body is crucial for converting occlusal forces into favorable compressive loads at the bone interface. Threads are specifically designed to minimize micromovement that could impair osseointegration, maximize initial contact, improve primary stability, increase surface area, compress the bone, and help dissipate loads at the implant-bone interface [21]. Bolind *et al.* [22] reported that threaded implants showed greater bone contact, while cylinder implants experienced more marginal bone loss.

Implant body designs with threads are effective in converting occlusal forces into compressive forces at the bone interface.

Factors Affecting Implant Surface Area

Increasing the number of threads per unit length on the axial plane increases the implant surface area in contact with the bone [4].

Thread Depth

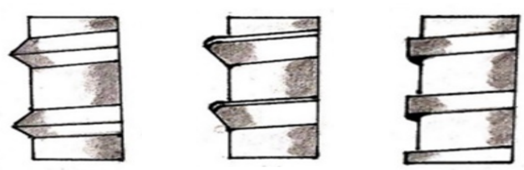
Deeper threads provide a larger contact surface area for the implant [4].

Thread Shape (Figure 3)

Square threads provide a greater percentage of bone-to-implant contact when compared to V-shaped or reverse buttress threads [4]. V-shaped and reverse buttress threads produce ten times more shear force than square threads. The reduction of shear force at the thread-bone interface allows for better compressive load transfer, which is crucial in cases of low bone density, short implant lengths, or high force magnitude [23].

Implant Surface Treatment

The surface treatment of implants plays a critical role in the success of short implants. A rougher microtopography, as opposed to a smooth, turned surface, increases the bone-to-implant contact area and accelerates osseointegration. This is especially beneficial in compensating for an unfavorable crown-to-implant ratio [4].



a) b) c)

Figure 3. a) V thread, b) reverse thread, and c) square thread

Surgical Procedures

Two-Stage Surgical Protocol

A two-step surgical protocol is recommended for short implants, as it ensures superior primary stability during the healing phase. Galvão *et al.* [16] suggested that this approach should be followed when placing short implants, with an interval of 4-6 months between the surgical and load stages for the maxilla, and 2-4 months for the mandible.

Modified Surgical Approach

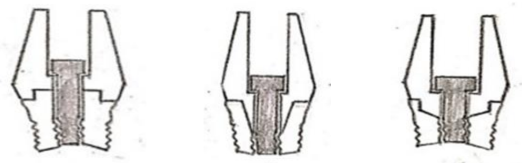
To improve initial implant stability, modifications to the standard surgical process can be made, such as bypassing certain drilling steps, like the countersink or last drill, in the regular sequence. For better outcomes, narrow drills should be used for final bone preparation, especially in cases of poor bone quality, where soft bone drilling techniques should be employed [24].

Prosthetic Considerations

Implant-Abutment Connection (Figure 4)

De Castro *et al.* [25] found that the Morse taper connection when compared to external hex abutment connections, resulted in less marginal bone loss and facilitated better bone growth around the implant shoulder.

Maeda *et al.* [26] conducted a study comparing stress distribution between external-hex and internal-hex connection systems using in vitro models. They observed that under horizontal loading, implants with external hex connections experienced greater strain at the cervical region, while internal hex implants demonstrated strain at the fixture tip. Additionally, internal hex connections provided a broader distribution of forces compared to the external hex design [26].



a) b) c)

Figure 4. a) external hex, b) Morse taper, and c) internal hex

Platform Switching

This technique helps preserve the crestal bone along the entire length of the implant, extending up to the collar [27-31].

Occlusal Table

Reducing the size of the occlusal table can help minimize offset loads on the implant.

Incisal Guidance

To accommodate the higher bite forces in the posterior regions, implants should adopt a biomechanical approach similar to that of natural teeth. Proper incisal guidance from the anterior teeth reduces lateral forces on the posterior teeth during mandibular movements [32-34].

Splinting

Splinting implants in soft bone enhances their functional surface area and minimizes the force transferred to the prosthesis, abutment screws, cement, and the bone-implant interface [4]. Ahumada-DeGirolamo et al. concluded that factors like implant size and its relation to crown height are significant considerations. Additionally, splinting adjacent crowns provides both biological and biomechanical benefits, especially for implants shorter than 8 mm or with an unfavorable crown-to-implant ratio. Each case must be evaluated individually, taking into account patient factors and parafunctional habits [35].

Factors Affecting the Survival Rate of Short Implants

Various factors can increase the likelihood of implant failure, which are considered risk factors. These factors, as reported in the literature, include the bone quantity and quality, the age of the patient, the experience of the clinician, the site of implantation, implant length, axial stress, and maintenance of oral hygiene. Other significant risk factors for failure include chronic periodontitis, poor bone quality, systemic health issues, smoking, untreated infections or cavities, advanced age, improper implant placement, acentric loading, parafunctional habits, not enough implants, and the failure of the implant to properly integrate with both hard and soft tissues. Additionally, a poorly designed prosthesis can contribute to implant failure [36].

Smoking

Research on rats suggests that smoking has a more detrimental effect on cancellous bone than cortical bone. Bain's prospective study on implant surgery demonstrated that patients who quit smoking one week before and eight weeks after surgery experienced significantly fewer implant failures (11.8%) compared to those who continued smoking (38.5%). Smokers had slightly higher failure rates in compromised maxillary bone (2.6%) compared to nonsmokers (1.9%) [37, 38].

Implant Location

While mandibular short implants generally have a higher success rate than maxillary ones, the location of short implants in the maxilla does not seem to be a significant risk factor for their success. Kim et al. found that implant failures were more common in the maxillary molar region, particularly with poor bone quality [39, 40]. However, Mezzomo et al.'s study [41] indicated a higher failure rate for single crowns supported by short implants in the mandible. The mandible, despite being cortical and rigid, is more prone to fractures, which may increase the risk of implant failure compared to the maxilla [42]. Monje *et al.* [1] reviewed multiple cases and found no significant differences in the survival rates of short implants based on their anatomical location.

Periodontitis

Studies have shown that individuals with a history of periodontitis are at a higher risk for biological complications, for example, peri-implantitis and bone loss around the implant, leading to lower success rates and survival outcomes compared to those without such a background [43-45]. Peri-implantitis has been identified as a major contributor to the failure of short implants. In a study by Hasanoglu Erbasar *et al.* [39], it was determined that neither the length nor the diameter of the implant significantly influenced its success. However, having a history of periodontitis and smoking negatively impacted short implant success. Therefore, it is strongly recommended that patients with periodontitis undergo proper periodontal treatment before implant placement, along with a comprehensive periodontal care plan to ensure the longevity of short implants [46-49].

Splinting

The practice of splinting implants has shown positive effects, especially when shorter implants are connected to longer adjacent ones, which can contribute to their prolonged success [5]. According to Akça *et al.* [50], the group of splinted implants (97.7%) had slightly higher success rates compared to non-splinted implants (93.2%). While the failure rate for non-splinted implants was higher, particularly when shorter implants were used or in male patients, the success of splinted implants was not significantly affected by other factors. The increased failure rate in men could be linked to stronger bite forces, although this was not conclusively determined in the study.

Loading Protocol

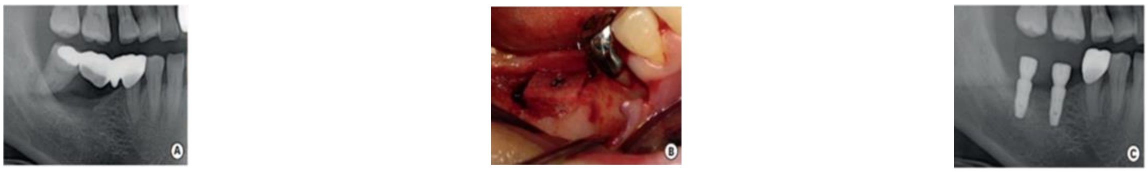
Weerapong *et al.* [51] found that immediate loading of mandibular molar implants showed similar survival rates, stability, and bone loss compared to traditional loading methods. Ayna *et al.* [52] observed favorable results with immediate loading protocols in the maxillary molar area, although the immediate loading group showed more bone loss and bleeding upon probing compared to delayed loading. This could be attributed to the poorer bone quality in the posterior maxilla or factors like the skill of the operator or the insertion torque [52]. In a study by Cannizzaro *et al.* [53], who applied a flapless approach for implant placement in the maxilla and mandible with immediate loading, the long-term results over nine years showed which immediate placement of short implants was successful.

Short Implants in the Mandible

For patients with total edentulism in the posterior mandible, the lack of bone height due to the presence of the lower alveolar nerve can complicate implant placement. Techniques such as vertical ridge augmentation and lateralization of the alveolar nerve are employed to increase bone availability, though these procedures often carry risks, including graft contamination and infections post-surgery [54-73].

Sáenz-Ravello *et al.* [74] concluded that the use of short implants in atrophic mandibular ridges resulted in fewer implant failures, less marginal bone loss, fewer biological issues, and higher patient satisfaction when compared to conventional implants placed after bone augmentation. Rosa *et al.* [75] also suggested that patients with mandibular atrophy may benefit from fixed full-arch restorations supported by short implants.

For patients with limited alveolar ridge height in the posterior mandible, there are three main treatment options: vertical ridge augmentation with implant placement, simultaneous implant placement with vertical ridge augmentation, and the use of short implants (**Figure 5a-5c**) [76].



a*) b*) c*)

a)

a**) b**) c**)

b)

a***) b***) c***)

c)

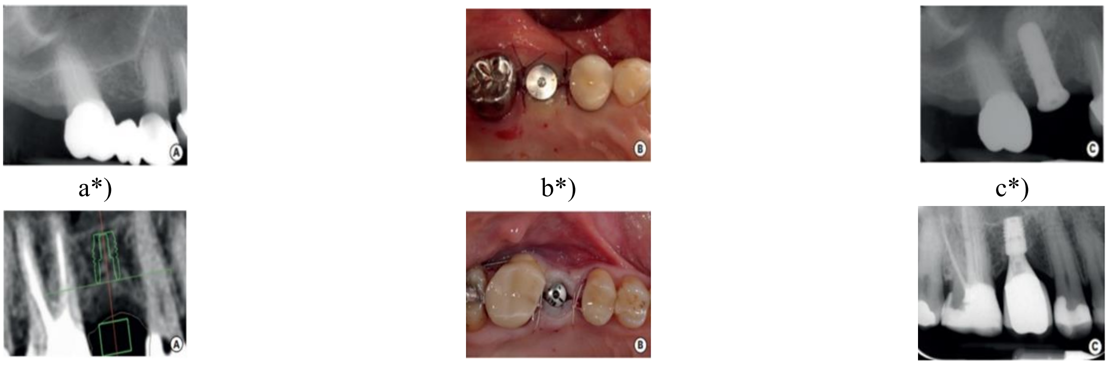
Figure 5. a*) a possible treatment approach for the posterior mandible when the remaining ridge height is under 8 mm; b*) primary vertical bone augmentation should be carried out; c*) subsequently, standard-length implants should be placed; a**) a treatment approach for the posterior mandible when the remaining ridge height is between 8 and 10 mm; b**, c**) a short dental implant is advised; a***) a treatment approach for the posterior mandible when the vertical bone height exceeds 10 mm; b***, c***) standard-length implants are recommended, with primary vertical bone augmentation followed by implant placement.

Short Implants in the Maxilla

Sinus pneumatization, a natural physiological process, particularly affects the maxillary posterior region, accelerating bone loss. As a result, the quantity and quality of bone often fall short of what is required for optimal three-dimensional (3D) implant placement [77]. To address the lack of sufficient bone height, procedures such as sinus augmentation using sinus elevation or autogenous bone are employed to make room for the placement of standard implants. However, these sinus floor elevation surgeries can lead to complications such as upper lip numbness, sinus membrane tears, localized infections, swelling, hematomas, and maxillary sinusitis. Short implants emerged as a promising technique to assist in implant placement in cases of reduced alveolar bone, offering a way to avoid harm to critical structures [3].

Yan *et al.* [78] reviewed the use of short implants (≤ 6 mm) and found that they present a viable option for sinus floor elevation in patients with atrophic posterior maxillae, showing similar survival rates, reduced marginal bone loss (MBL), and fewer postoperative complications compared to traditional approaches.

Several treatment alternatives are available, as shown in **Figure 6** [76].



a*) b*) c*)

a**) b**) c**)

Figure 6. a*) a possible treatment approach for the posterior maxilla when the vertical bone height exceeds 8 mm; b*, c*) for cases with a vertical ridge dimension greater than 8 mm, a transcrestal sinus elevation method may be used if standard-length implants are chosen; a**) a treatment solution for the posterior maxilla with a vertical bone height ranging from 6–8 mm; b**, c**) in this case, the use of a short dental implant is recommended.

Discussion

The choice of implant length plays a vital role in determining both the success of the prosthesis and the long-term survival of the implants. Placement in the posterior regions of the maxilla and mandible, where bone quality and volume are often insufficient, has traditionally been a challenging aspect of implantology. While longer implants can be utilized with advanced procedures such as bone augmentation and sinus lifts, these techniques can be more invasive. As a result, there is a growing preference for less invasive alternatives in areas with compromised bone. In this context, short implants are gaining recognition in the field of implant dentistry. Enhancements to the surface geometry and texture of implants have led to an expanded bone-implant contact area, which contributes to improved primary stability during the osseointegration process.

Conclusion

Short dental implants offer a viable solution for patients hesitant to undergo augmentation procedures. When applied following strict clinical protocols, these implants can be deemed both safe and predictable, particularly for atrophic ridges in the maxilla and mandible. However, further high-quality research is necessary to assess the long-term success and effectiveness of short implants, considering factors such as implant location and overall success rates.

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