Current Therapeutic Options for Implant-Supported Rehabilitation of Severely Atrophic Mandibles

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Abstract
The implant-supported rehabilitation of atrophic mandibles (AM) with severe bone resorption is challenging for both surgical and prosthetic procedures due to the high risk of mandible fracture during implant surgery and postoperatively due to the masticatory load. The aim of case presentations was to demonstrate treatment alternatives for patients with AM who required oral rehabilitation with osseointegrated implants (OIs) according to the residual mandibular bone volume. When bone is 9 mm in height, the ideal treatment is the use of narrow, short OIs. When the bone height is 5 to < 9 mm, mandibular reinforcement with reconstruction plates using the intraoral approach and simultaneous placement of osseointegrated implants are proposed. In cases where bone height is < 5 mm, the choice of treatment is mandibular reconstructive surgery with an autogenous bone graft and biomaterials. The fundamental principles of this protocol are to reduce the morbidity and complications associated with the surgical procedure, which would reduce both the time and cost of full dental rehabilitation. The choice of the technique for mandibular reconstruction should be indicated according to the magnitude of the atrophy.

Keywords
► dental implants
► atrophic mandible
► bone atrophy
► oral rehabilitation

Patients with mandibular atrophy often have problems using full removable dentures, resulting in a lack of stability, intolerance to loading by the mucosa, pain, feeding and diction difficulties, loss of adjacent soft tissue support, and abnormal facial appearance. Therefore, many of these patients should be perceived as having an oral disability, as oral rehabilitation will often result in maxillofacial recovery.

The rehabilitation of complete edentulous mandibles with osseointegrated dental implants was first performed by Brånemark et al.2 They reported great success, predictability, and effectiveness; this form of rehabilitation treatment is now well grounded in the literature, with more than 40 years of follow-up and proven successes. However, in cases where the patient presents severe mandibular bone atrophy, dental rehabilitation with osseointegrated implants (OIs) becomes less predictable and has an increased complication rate.1,3 Mandibular fracture is one of the most severe complications; these fractures have been widely described in the literature along with cases of osteomyelitis, permanent paresthesia, and poor longevity of osseointegrated implants.3

In 1996, Luhr et al4 proposed a classification of mandibular atrophy according to the height of the bone base. They considered the mandibles to be atrophic when the bone height was ≤ 20 mm. Mandibles 16 to 20 mm in height were classified as class I atrophy, those 11 to 15 mm as class II atrophy, and those ≤ 10 mm as extremely atrophic or class III atrophy.4

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The functional rehabilitation of severely resorbed mandibles remains a prosthetic and surgical challenge due to the extreme reduction in the supporting bone structure and due to the progressive nature of the resorption process.5

Many alternatives for the treatment of atrophic mandibles (AM) are found in the literature, including transmandibular implant,6,7 short implants,8–10 distraction osteogenesis,11–13 and bone substitutes followed by implant installation,14 reconstructive techniques such as autogenous grafts to the mandible base, segmental osteotomies with interposition of grafts, the sandwich technique and inverted sandwich technique,15,14–16 and, most recently, reinforcement of the atrophic mandible with reconstruction plates concomitant with dental implant surgery.17–20

None of these alternatives is considered the gold standard for rehabilitation of an atrophic mandible. Each has its own specific advantages and disadvantages, including different morbidity and associated time and treatment costs. Most of the surgical techniques described in the literature have high complication rates, especially distraction osteogenesis and the reconstructive techniques.3,6,11,21,22 Blackburn et al23 reviewed the literature to evaluate the level of evidence in published studies for the outcomes of bone augmentation before implant surgery for atrophic jaws; they concluded that the level of evidence was of a low order. No meta-analysis of outcomes was possible due to the degree of heterogeneity found in the articles reviewed, and future studies with a higher level of evidence are needed.23

This case presentation aims to present alternatives to the implant-supported rehabilitation of class III mandibles according to the type and magnitude of bone atrophy. We propose a protocol for the complete rehabilitation of AM based on the remaining bone height and width (Table 1). We must also remember that the greatest number of patients with this pathological condition are elderly. The fundamental principles of this protocol are to reduce the morbidity and complications associated with the surgical procedure, thus reducing the time and cost of full dental rehabilitation.

Rehabilitation of Atrophic Mandibles

Type I Atrophic Mandible Rehabilitation: Mandibles with a Minimum Width of 5 mm and Height of 9 mm

The Type I protocol for the rehabilitation of an atrophic mandible is the use of short implants. Currently, this treatment option is associated with technological advances of modern implantology, as it uses implants that are both short and have a reduced diameter—the so-called narrow platform. Following this advance, the possibilities of the Morse taper connection should be emphasized due to its improved biomechanics; it allows rehabilitation resistance very similar to rehabilitation with regular platform implants. New titanium–zirconium alloy implants permit rehabilitation with narrower implants because they allow greater resistance and have higher strength compared with conventional implants.24,25

Table 1: Proposed treatments for severe atrophic mandibles according to bone availability

<table>
<thead>
<tr>
<th>Classification of atrophy</th>
<th>Proposed treatment</th>
<th>Bone height</th>
<th>Bone width</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Short (6, 7, 8, or 9 mm) and narrow (3.3 or 3.5 mm) implants</td>
<td>&gt; 9 mm</td>
<td>Minimum 5 mm</td>
<td>Low cost and reduced treatment time</td>
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<td></td>
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<td></td>
<td>Low morbidity</td>
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<td>Local anesthesia</td>
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<td>Predictable results.</td>
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<tr>
<td>Type II</td>
<td>Short and narrow implants plus 2.0-mm reconstruction plate</td>
<td>&lt; 9 mm and &gt; 6 mm</td>
<td>Minimum 5 mm</td>
<td>Reduced treatment time, especially when immediate loading is possible</td>
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<td></td>
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<td></td>
<td>No need for donor site morbidity (without autogenous graft)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Intraoral approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low morbidity</td>
</tr>
<tr>
<td>Type III</td>
<td>Autogenous bone graft reconstructive surgery in the anterior mandible prior to implant placement surgery</td>
<td>&lt; 5 mm</td>
<td>–</td>
<td>Intraoral approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Autogenous bone graft associated with biomaterials reducing donor site bone volume needed</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Possibility for removable temporary prosthesis during bone grafts incorporation period</td>
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<td></td>
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<td>Dental implants platform is placed in the residual mandibular bone, reducing peri-implant bone loss over time.</td>
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</tbody>
</table>
The use of this technique can be observed in Figs. 1 and 2, which show a clinical case of mandibular atrophy of a patient classified by Luhr as class III, with 9 mm of bone height in the anterior mandible (Fig. 1). The patient was treated using osseointegrated dental implants with Morse taper connections 3.5 mm in diameter and 8 mm in length. Abutments were installed at the same time as the implant surgery installation; transfer molding for immediate loading system rehabilitation, with installation of a definitive full-arch implant-supported hybrid prostheses, was also performed (Fig. 2).

Some of the problems posed by this technique involve cases where the mandibular atrophy is more pronounced in the horizontal direction (width < 5 mm), which can lead to increased bone fragility while installing the OIs. This can induce a mandibular fracture. The use of narrow implants can minimize this type of complication, but cannot prevent it.

**Type II Atrophic Mandible Rehabilitation: Mandibles with a Minimum Width of 5 mm and a Height of 6 to 9 mm**

The Type II protocol for rehabilitation of AM is used for mandibles 6 to < 9 mm in height. This technique uses a mandibular reconstruction plate simultaneously with OIs installation and minimizes the chances of mandibular fracture (Fig. 3). Furthermore, due to the reinforcement provided by the titanium plate, immediate loading rehabilitation can be achieved as long as the OIs achieve adequate initial stability.

This rehabilitative sequence may be observed in Figs. 4–6. A 68-year-old patient with upper and lower edentulism and severe mandibular atrophy, with a lower bone height of < 9 mm (Fig. 4) was rehabilitated using implant-supported prostheses. The rehabilitative sequence was based on the principle of concurrent reinforcement of the mandible with a 2.0-mm locking system reconstruction plate and installation of the osseointegrated implants, thereby preventing mandibular fracture of the weakened atrophic mandible. The reconstruction plate should preferably be prefolded or prebent using a biomodel made from the patient's computerized tomography (CT) scan to reduce the surgical time and ensure more accurate adaptation (Fig. 5). An acrylic implant surgical guide can be manufactured to determine correct implant placement that does not interfere with the screws used for the reconstruction plate (Fig. 6).

The surgical procedure must be performed while the patient is under general anesthesia. The surgical approaches used in this case were intraoral access to install the plate and implants (Fig. 7) and bilateral transcutaneous accesses to fix the distal plate screws. The integrity of the mental neurovascular bundle was maintained during surgery. In
this technique, the inferior alveolar bundle is displaced because in most cases of extensive bone atrophy, the mental nerve tends to be positioned more superficially above the alveolar ridge.

After positioning the reconstruction plate using intraoral and transcutaneous surgical access, with a surgical guide preconstructed on a patient’s biomodel, four titanium implants are installed, as described in a Branemark protocol. Often, despite bone atrophy, bone quality and quantity are adequate for immediate prosthetic transfer of the OIs and immediate loading. After administration of anesthesia discharge, the patient underwent transfer molding, followed by the prosthetic procedures necessary for immediate loading rehabilitation. Three days after surgery, a Branemark protocol-type with a metal bar and acrylic aesthetics was installed (► Fig. 8).

**Type III Atrophic Mandible Rehabilitation: Mandibles < 5 mm in Height**

The Type III protocol for rehabilitation of an atrophic mandible is indicated when the patient’s atrophy prevents rehabilitation.
using OIs, such as in medical conditions in which the remnant mandibular bone is < 5 mm in height (► Fig. 9). In such cases, it is prudent to perform bone reconstruction prior to implant placement. The use of biological and/or synthetic biomaterials is indicated for more predictable results and less overall morbidity associated with the reconstructive surgery.

The surgical procedure was performed using an autogenous bone graft from the iliac crest for reconstruction of the anterior mandible in association with a xenograft (Bio-Oss, Geistlich Pharma) and morphogenetic protein rhBMP-2 (Infuse Bone Graft, Medtronic) (► Figs. 10-12).

In this clinical situation, it is necessary to allow incorporation of the bone into the graft site for at least 6 months. Imaging examinations permit the evaluation of the reconstructed bone for implant surgery planning (► Fig. 11).

At that time, reverse prosthetic planning and the production of surgical guides are performed, and OIs with Morse taper connections are installed. In most cases, good initial
stability of the implants is achieved, and prosthetic abutments can be installed for rehabilitation with an immediate loading system. Full-arch metal-acrylic implant-supported prosthesis are fabricated and installed 72 hours after surgery (Fig. 12).

Discussion

Transmandibular implants for the treatment of an atrophic mandible without reconstructive procedures were described by Bosker and van Dijk in 1989. Studies show complication rates ranging from 7.8 to 22.2%, including loss of osseointegration, mandibular base bone inflammation and/or fistula, postoperative infections, and fractures.6 These fractures have a high occurrence rate when this system is used for
severely resorbed mandibles. This technique also recommends extra oral access for proper execution.

In 1998, Perry described a technique for the treatment of AM using osseointegrated subperiosteal implants and implants associated with iliac crest grafts, with the aim of extending the support of the prosthesis to the posterior region of the mandible. The complications of this technique included paresthesia of the inferior alveolar nerve followed by hyperesthesia, graft exposure, and a 50% loss of the graft. This technique seems to have a few advantages due to the morbidity of the procedure and the type of prosthesis proposed for the patient’s rehabilitation. The patients were ultimately rehabilitated with removable dentures of the overdenture type.

In 1995, Keller described a technique in which implants of the interforamen region in mandibles were installed that extended through both cortices and elevated the periosteum of the mandibular basal bone with the apex of the implant, leading to clot stabilization and bone tissue formation after wound closure. Complications including mandibular fracture occurred during the wound closure period following the

Fig. 9 (A–C) CT scan showing a Type III severely atrophic mandible (< 5 mm). CT, computed tomography.
procedure. The incidence of mandibular fractures in this type of patients reported in the literature is yet to be determined. In 2012, Almasri and El-Hakim in a PubMed search revealed 13 cases of fractured atrophic mandible secondary to implant placement.

The technique of distraction osteogenesis has advantages compared with grafting procedures, as it does not require a donor area. This difference results in lower morbidity and the presence of vital bone in the distraction area (and therefore in the region that will receive the implant) in addition to an increase in soft tissue. However, complications such as mandibular fractures, infection, and necrosis of the upper fragment have been described in AM. Complications are also described by Perdijk et al who reported a complication rate of 66% in AM, contraindicating that the procedure could be performed on mandibles < 10 mm height.

In principle, the use of short implants is a very interesting treatment, as the procedure is quite safe, relatively simple, and has low morbidity. However, the risk in this isolated type of treatment lies in the possibility of mandibular fractures, as the

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**Fig. 9** (Continued)

**Fig. 10** Surgical procedure for mandibular reconstruction. (A) Surgical access and exposure of the mandibular bone. (B) Fixation of the autogenous bone block graft to the mandibular base. (C) Xenograft (Bio-Oss) and bone morphogenetic protein rhBMP-2 (Infuse Bone Graft) were associated with the autogenous bone.
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osteotomy for implant placement removes bone tissue from an already weakened mandible. Although this is a rare complication, treatment is difficult. The use of short implant therapy is indicated for cases of moderate atrophy of the mandible. Treatment of AM with only short implants is usually associated with mandibular fractures during the trans- or postoperative period, as described. To minimize the risk of complications, the use of narrow diameter implants (3.5, 3.3, or 2.9 mm) should be emphasized. The recent credibility attributed to narrow implants reinforced by zirconia, which provides sufficient strength to withstand masticatory and occlusal loads, encourages the use of these new technologies in severe AM. The use of this type of implant leads to thicker lateral and medial remnant bone, decreasing the risk of fracture. However, as these implants require prosthetic rehabilitation resistance, the use of OIs with Morse taper connections seems to be an interesting option, as other types of narrow implants may have inefficient prosthetic biomechanics.

In Type I AM, with less than 5 mm in width, it should be decided, based on the remaining bone volume, whether to perform the Type I protocol (with possible complications such as mandibular fracture in mind), or to perform the mandibular reinforcement with a reconstruction plate, as proposed in Type II protocol. The decision must be planned individually and in the remaining total bone height and width. In cases where bone width is less than 5 mm, there is an increased risk of mandibular fracture due to a lack of residual bone around implants. To reinforce a severely atrophic mandible, a reconstruction plate of the 2.0-mm locking system adjusted on the mandibular base can be used with narrow implants. Prior to surgery, the plate should be adapted on a biomodel of the patient, due to advantages such as the opportunity to better study the case and reduce the surgical time. Using the same biomodel, it is possible to establish the positioning of the implants and the plate screws before surgery so that the screws in the anterior region do not interfere with the positioning of the implants.

The plate can be installed via intraoral access with preservation of the mental neurovascular bundle, which requires only two small transcutaneous accesses points for installation of the most distal plate screws. We reinforced the need for displacement of the inferior alveolar nerve by bilaterally repositioning it more posteriorly, so that the reconstruction plate could be installed via intraoral access. The type of osteosynthesis indicated is the 2.0-mm locking system. With this system, hardware with a smaller volume, plate, and screws may be inserted, and the locking system permits increased biomechanical resistance of the plate. The smaller volume also facilitates an intraoral surgical approach and decreases the chance of plate exposure in the intraoral environment during the healing period. This material provides adequate resistance to the mandible, allowing patients to return to their routine quickly and with minimal morbidity. Thus, rehabilitation is fast, safe, and predictable.

The literature regarding atrophic mandible treatments includes various bone reconstruction techniques, such as onlay and interpositional grafts, which enable OIs placement either during the same surgical procedure or after the graft incorporation period. When implants are placed at the same time as bone grafts, the difficulty in planning ideal implant positioning may be a disadvantage. In addition, in these cases, osseointegration into the grafted area can be unpredictable. The two-stage techniques have the disadvantage of requiring a second surgical procedure. Moreover, it is not possible to predict how much the graft will be remodeled around the implant. Bone graft resorption using the sandwich technique seems minor compared with onlay grafts. Complications associated with autogenous grafting techniques include sensory disorders of the mental nerve, suture dehiscence, infection of the grafted area, and major morbidity. Most cases require extraoral incisions.

With the increasing development of modern implantology, large reconstructive surgeries have become less frequent in clinical practice. However, while treating severe bone atrophy, implant therapy is often impossible without previous reconstructive procedures. It would be impossible to perform the Type III atrophic mandible reconstruction protocol described in this work using the reconstruction plate, as the extremely low bone height would prevent placement of the robust screws of the 2.0-mm system and the osseointegrated implants. Mandibular bone reconstruction is required in these situations.

Since bone remodeling of the onlay grafts for vertical bone augmentation is unpredictable, it is a good option to accommodate the graft at the mandibular base, allowing the implant platforms to be placed in the patient's original bone instead of grafted bone. To compensate for possible

Fig. 11 Panoramic radiograph taken 6 months after surgery showing adequate bone volume in the anterior mandible.

Fig. 12 Panoramic radiograph after rehabilitation with implant-supported prostheses.
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...with the therapeutic approaches employed in severely AM rehabilitation protocol.

Currently, the intraoral approach is recommended for surgery. This technique has advantages: it allows for faster postoperative recovery with no apparent extraoral scars, and often results in a shorter hospital stay. However, surgeons should pay special attention not to damage the mental neurovascular bundle during incision and soft tissue detachment, as this structure is often found on the mandibular edge due to extensive atrophy. In some cases, the inferior alveolar neurovascular bundle is exposed for most of its length along the mandibular edge. We consider that the disadvantage of higher inferior alveolar bundle paresthesia due to nerve manipulation is of minor importance when compared with an atrophic mandible fracture or the morbidity of reconstructive surgery. Reinforcing the mandible with a reconstruction plate not only prevents a mandibular fracture, but also enhances the possibility of immediate prosthetic rehabilitation procedures, making it unnecessary to use a removable prosthesis during osseointegration period and/or the bone healing period when bone reconstruction is needed.

The age range of most of these patients should not be disregarded. Elderly patients have a higher incidence of systemic diseases, and treatment planning should be more conservative and as short as possible. That is a primary reason to emphasize the importance and advantages of the Type I and Type II protocols, eliminating long treatment planning and reducing the morbidity of reconstructive procedures.

We must mention a technique recently published by Gellrich et al which consists of the accomplishment of a treatment strategy through the installation of subperiosteal implants through a rigid fixation anchorage system.31,32 Type of treatment, known as IPS-Dental, aims at the execution of customized connections for patients who go against the characteristics of traditional implantology and can be used in cases of AM and patients with a history of extensive bone defects, such as post treatment of oral cancer. Therefore, it is a promising technique for the minimally invasive rehabilitation, with reduction in costs and treatment time and in accordance with the concepts of modern implantology. Although the technique may be considered as a potential treatment plan for patients with extremely AM, the authors of this paper are yet to become familiar with the technique. Since few cases with a short follow-up time have been published, in addition to not having a specific protocol or indication for these types of patients, this technique was not initially included in the AM rehabilitation protocol.31,32 All clinical cases of severe mandibular atrophy are currently addressed by all oral and maxillofacial surgeons linked to our service for over 10 years, using the approaches suggested in this study. We may now consider that our complications associated with the therapeutic approaches employed in severely AM are close to zero. More than 25 patients with severe mandibular atrophies have already been treated with the techniques presented here, and the vast majority of them had immediate loading implant prostheses, as these were associated with the classifications I and II suggested by us. The lower likelihood of complications, as well as the faster and less invasive treatments with shorter periods of hospitalization, make these techniques attractive to patients. Even more, because many of these patients are elders with systemic fragility, which makes us think twice about the issue of surgical invasiveness. In numbers, we currently have 4 patients treated through Protocol III, 8 patients treated through Protocol II, and 13 patients treated through Protocol I.

**Conclusion**

Treatment of AM using short, narrow implants is good for Type I cases. Treatment should preferably attempt to use implants with Morse taper connections, as these provide a better biomechanical implant–prosthesis system, even with small-diameter implants. In Type II AM, the use of a reconstruction plate and the installation of the implants in the same surgery are effective; the material provides adequate resistance for the mandible, preventing fractures during the trans- and postoperative periods and allowing immediate oral rehabilitation. In turn, in Type III cases, a bone graft should be considered for mandibular reconstruction prior to implant placement, and all modern resources of bone tissue engineering should be pursued. Therefore, it is possible for oral rehabilitation procedures to reach all patients with mandibular atrophy and to rehabilitate these patients safely, predictably, and with minimal morbidity.

**Conflict of Interest**

None.

**References**

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