Decision making process for the implant-supported prosthetic rehabilitation of the atrophic posterior maxilla in partially edentulous patients

Ilaria Franchini*
Matteo Deflorian*
Maria Cristina Rossi*
Matteo Capelli*
Tiziano Testori**

** Galeazzi Orthopedic Institute, Dental Clinic – IRCCS –Department of Health Technologies University of Milan, Italy*
***Head of the Section of Implant Dentistry and Oral Rehabilitation Galeazzi Orthopedic Institute, Dental Clinic – IRCCS – Department of Health Technologies University of Milan, Italy*

Background Loss of alveolar bone in the posterior maxilla and progressive pneumatization of the maxillary sinus following tooth extraction result in moderate to severe crestal bone atrophy thus influencing implant placement.
Surgical procedures like sinus lift surgery with lateral approach or sinus lift with crestal approach and the use of short implants are considered to be predictable techniques.
The clinical indication for the correct surgical technique and implant-supported prosthetic rehabilitation strongly depends on the individual anatomical situation and on the amount of residual crestal bone. The aim of this paper is to provide a precise diagnostic classification and decision making process, in order to determine the most appropriate procedure in the implant-supported prosthetic rehabilitation of the lateral-posterior maxillary edentulism.

Key words:
maxillary atrophy;
maxillary sinus floor elevation;
sinus grafting

Introduction

In the implant-supported prosthetic rehabilitation of the lateral-posterior maxilla, unfavorable anatomical conditions are frequently observed. Posterior tooth loss and progressive pneumatization of the maxillary sinus result in crestal bone atrophy of different severity for each individual patient. The degree of crestal bone atrophy may influence implant placement when following a traditional protocol. Several clinical studies regarding surgical techniques for the treatment of complex cases have been published, and currently sinus lift techniques according to Caldwell-Luc modified by Tatum (1), sinus lift techniques with crestal approach (2) and the use of short implants (3) and tilted implants (4) are considered to be highly predictable procedures in long and medium term. However, indications to the different surgical procedures are still not ultimately defined, due to the overlapping of different protocols in relation to the quantity of residual bone in the cranial-caudal direction.
The aim of this paper is to provide a precise diagnostic classification and decision making process, in order to determine the most appropriate procedure in the implant-supported prosthetic rehabilitation of the lateral-posterior maxillary edentulism.

Anatomical diagnosis

Following tooth loss, the crestal bone undergoes a physiological remodeling processes. Schropp et al. (5) documented a horizontal resorption of the crestal bone of approximately 50% and an average decrease of the vertical height in the center of the crestal bone of approximately 1 mm in an interdental post-extraction site 12 months after a single tooth extraction. Furthermore, periodontal disease, which is considered to be one of the main reasons of tooth loss, also increases alveolar bone loss.
The alveolar process of the posterior maxilla is adjacent to the maxillary sinus, which is in continuous expansion even in patients with healthy teeth. Tooth loss seems to further accelerate sinus pneumatization (6).
Bone loss in post-extraction sites of the posterior maxilla occurs mainly according to three primary vectors: the horizontal vestibular-palatal vector, the cranial vector and the caudal vector. The resulting volumetric variation of the edentulous bone crest modifies the three-dimensional relationships between the arches. As a result, implant rehabilitation of the posterior maxilla is extremely demanding in unfavorable anatomical conditions.
Remodeling of the alveolar process in post-extraction sites results in anatomical situations, which can be classified as follows, corresponding to increasing severity of the atrophy.

› Adequate crestal bone thickness with almost maintained harmonic arch form and adequate inter-arch distance.
› Adequate crestal bone thickness with almost maintained harmonic arch form and increased inter-arch distance.
› Inadequate crestal bone thickness with inverse inter-arch relationship and adequate inter-arch distance.
› Inadequate crestal bone thickness with inverse inter-arch relationships and increased inter-arch distance.

When determining the therapeutic indication, it is of utmost importance to consider the type of edentulism, the quantity of residual bone tissue in the cranial-caudal as well as in the vestibule-palatal direction and the resulting relationship between upper and lower jaw.

Therapeutic alternatives

In the last decade, scientific development in implant dentistry has determined highly improved clinical solutions aimed to treat compromised anatomical situations in the edentulous upper jaw.
Sinus lift with lateral and crestal approach, the use of short implants and the use of tilted implants inserted in pre- and post-sinusal position are the most reliable and predictable techniques (6, 7, 8, 9, 10).

Sinus lift with lateral approach

The sinus lift technique with lateral approach is a well-documented procedure in literature. Several studies report high implant survival rate in relation to the performed bone augmentation technique (7, 11).
The lateral approach to the maxillary sinus, performed according to Caldwell-Luc procedure modified by Tatum (1), require the elevation of a full-thickness flap following crestal or palatal incision in the residual keratinized gingival tissue. An oval-shaped antrostomy, is performed according to the mesio-distal extension of the maxillary sinus and the planned implant position. The presence of one or more Underwood septa may require two or more antrostomies, performed each mesially and distally to the septum. The Schneiderian membrane is lifted first cranially, and subsequently mesially, distally and caudally, until the medial wall of the maxillary sinus is visible. The graft material is placed initially in the less accessible areas — anterior and posterior recess — and in contact with the bone walls, in order to obtain adequate blood supply, which is an essential condition for the succesful integration of the graft (Fig. 1a-c, Fig. 2a-g).
Several authors have evaluated the material recommended for maxillary sinus lift procedures: whether autogenous, alloplastic or xenogenous grafts, used either individually or combined. All materials show good graft integration and high survival rate of implants inserted in augmented sinus and subsequently functionally loaded loaded (12, 13, 14, 15).
The use of rough-surfaced implants (7, 11) and the placement of membranes on the antrostomy to protect the graft (16, 17) both show to further optimize implant survival rates.
The quantity of the residual alveolar bone is the critical factor when implant placement is performed simultaneously with bone augmentation procedure:

FIG. 1
Sinus lift with lateral approach involves a generally oval-shaped antrostomy at the vestibular wall of the maxillary sinus and the elevation of the sinus membrane up to the lateral wall of the nose. Image courtesy of ACME Editore (from: Testori T, Wallace SS, Weinstein RL. La chirurgia del seno mascellare. ACME Editore 2005)

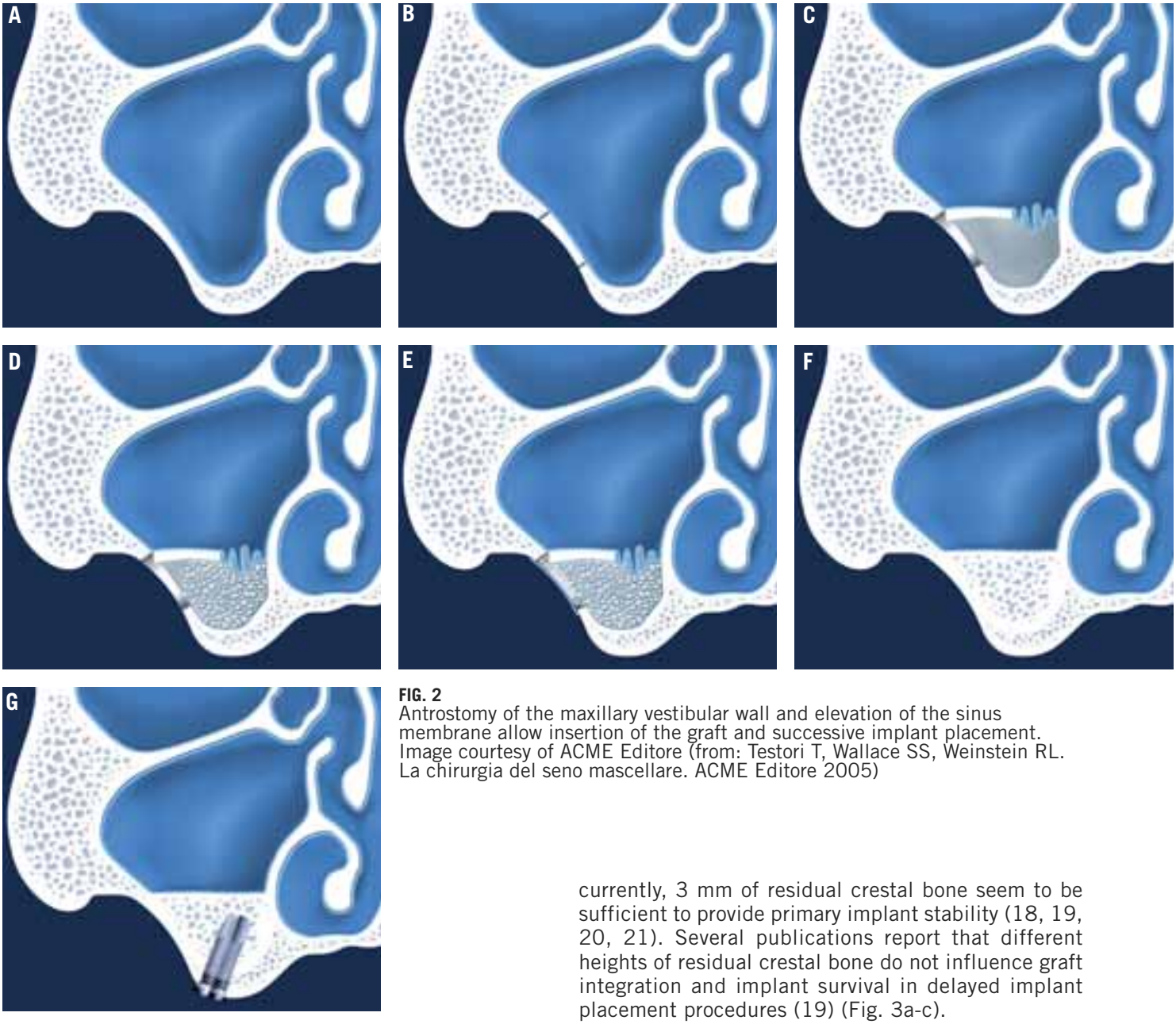


FIG. 2
Antrostomy of the maxillary vestibular wall and elevation of the sinus membrane allow insertion of the graft and successive implant placement. Image courtesy of ACME Editore (from: Testori T, Wallace SS, Weinstein RL. La chirurgia del seno mascellare. ACME Editore 2005)

currently, 3 mm of residual crestal bone seem to be sufficient to provide primary implant stability (18, 19, 20, 21). Several publications report that different heights of residual crestal bone do not influence graft integration and implant survival in delayed implant placement procedures (19) (Fig. 3a-c).

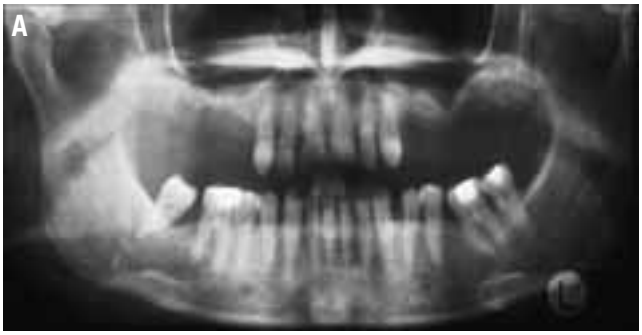
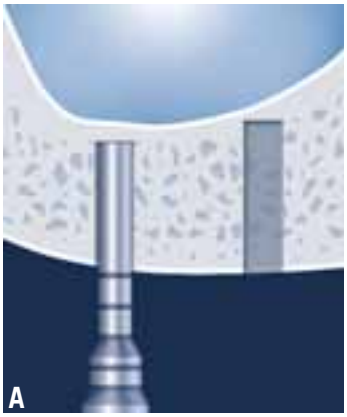
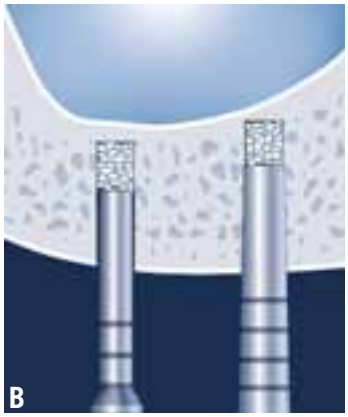


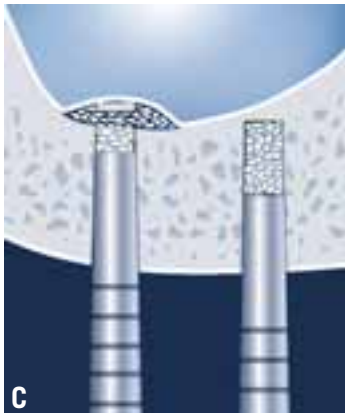
FIG. 3
Bilateral implant-prosthetic rehabilitation of edentulous ridge with height < 3 mm (a) by means of sinus lift with lateral approach (b) and delayed implant placement (c).

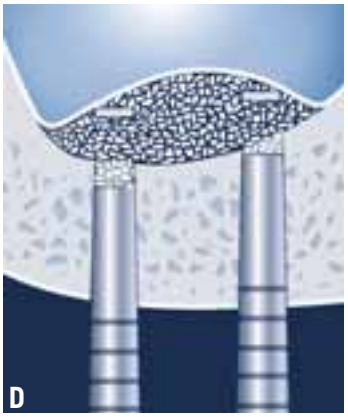
Sinus lift with crestal approach

In order to reduce surgical trauma and post-operative complications associated with the lateral approach technique, Summers (2) suggested the maxillary sinus lift procedure with a crestal approach. This procedure combines osteotomy of the alveolar ridge, infraction of the sinus floor cortical bone and subsequent elevation of the Schneiderian membrane, using calibrated osteotomes, with graft material (Fig. 4a-g) (22, 23, 24).
Modifications of the crestal technique don't seem to influence implant survival (25, 26). Even in this procedure, residual bone height is the critical factor for the survival of inserted and functionally loaded implants: 4-6 mm height are considered to be sufficient to perform implant placement simultaneous to bone augmentation procedures with predictable results (8, 27, 28).









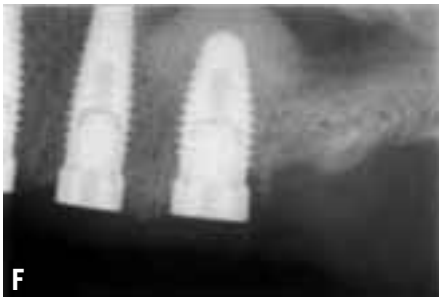


FIG. 4
Sinus lift with crestal approach involves initial preparation of the site up to the sinus floor (a), expansion by means of osteotomes (b), infraction of the sinus floor (c), elevation of the membrane with graft (d), and simultaneous implant placement (e, f). Radiographic evaluation after 24 months shows graft stability (g). Image (a-d) courtesy of ACME Editore (from: Testori T, Wallace SS, Weinstein RL. La chirurgia del seno mascellare. ACME Editore 2005)

Short implants (< 10 mm)
From a biomechanical point of view, the significance of the crown / implant ratio has been revisited, since occlusal load has been showed to be substantially transferred to the bone in the coronal implant portion (29, 30).
The development of new implant macro- and micro-designs allowed to obtain high secondary stability and to shorten healing time, even in low-density bone and unfavorable biomechanical conditions (Fig. 5) (31, 32, 33). In addition, less traumatic surgical techniques have been developed to provide higher primary stability (32, 34, 35, 36).
Currently, implant rehabilitation supported by short implants is considered to be predictable treatment if the following prerequisites are fulfilled:
› micro-rough implant surface(32, 34, 35, 36);
› implant site under-preparation using minimal invasive surgical techniques, in order to achieve high primary implant stability, especially in low-density bone (9, 37, 38);
› reduced occlusal tables of implant prosthesis in order to reduce the occlusal load (34, 39, 40, 41);
› correct treatment planning including the evaluation of the correct home care procedure for the maintenance of the implant-supported prosthetic restoration, considering the decreased vestibulum depth and the modified crestal bone position (9, 34).

Pre- and post-sinusal tilted implants
Maxillary sinus hyper-pneumatization is frequently associated with insufficient bone availability for implant insertion in the pre-maxilla and in the maxillary tuberosity. Several studies demonstrated that implant mesio-distal tilting to the occlusal plane does not have a negative influence on implant survival rate (10, 42, 43). The less invasive surgical approach involves the insertion of distally tilted implants parallel to the mesial wall of the maxillary sinus and mesially tilted implants in the maxillary tuberosity, exclusively in residual bone: this procedure allows to create mesial and distal posts for the implant-supported prosthetic rehabilitation with lower morbidity (Fig. 6a, b). For this reason, it is recommended in elderly patients and in subjects with severe systemic diseases or with maxillary sinus diseases, where more invasive and sophisticated surgery is not indicated.

FIG. 5
Implant-prosthetic rehabilitation of the right lateral-posterior maxilla with short implants (< 10mm) and splinted prosthetic crowns.

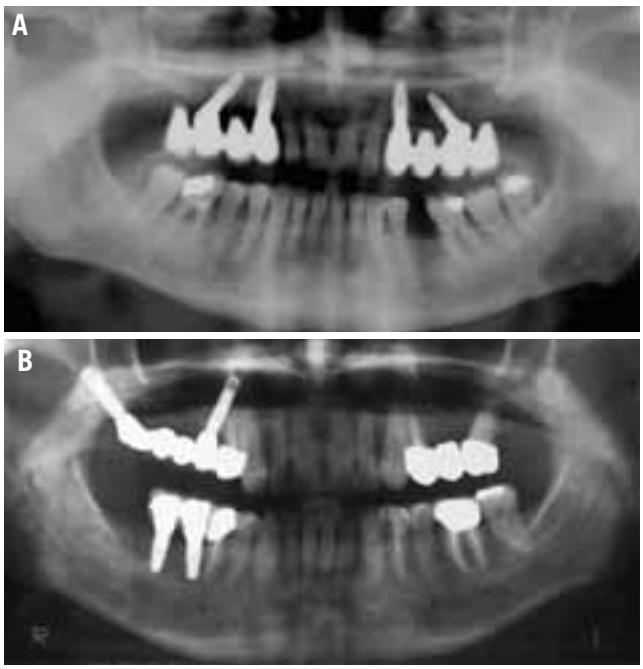


FIG. 6
Implant-prosthetic rehabilitation of the posterior maxilla with distally tilted pre-sinus implants (a) and distally tilted pre-sinus implant and mesially tilted post-sinus implant (b).

Indication for the implant-supported prosthetic reahabilitation of atrophic posterior maxilla

Remodeling of the posterior maxillary alveolar process leads to different degree of atrophy and anatomical situations, requiring different surgical approaches (Fig. 7, Tab. 1).

1. Type A: sinus pneumatization Unaltered three-dimensional inter-arch relationship and harmonic arch form allow prosthetically-guided implant-prosthetic rehabilitation without appositional bone grafts. Soft tissue augmentation may improve aesthetic results.
Residual crestal bone height is the critical factor in the surgical therapeutic choice.
› When residual bone height is less than 3 mm, it is insufficient in providing primary implant stability when simultaneously performed with sinus lift procedure, and needs to be augmented before implant placement. Therefore, the therapeutic indication includes sinus lift with lateral approach and delayed implant placement.
› When residual bone height is 3 mm, it may be sufficient for implant stabilization. Implants can be

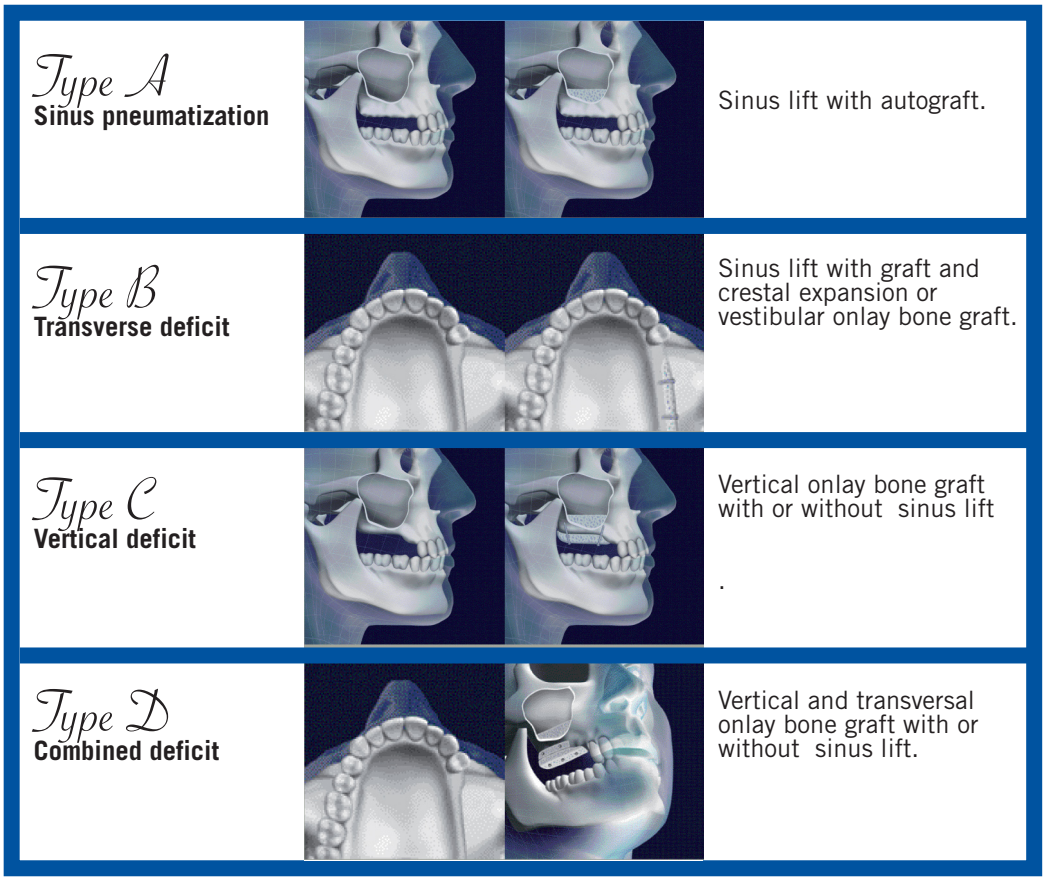


FIG. 7
Remodeling of the posterior maxillary alveolar process leads to different anatomical situations, requiring different surgical approaches.
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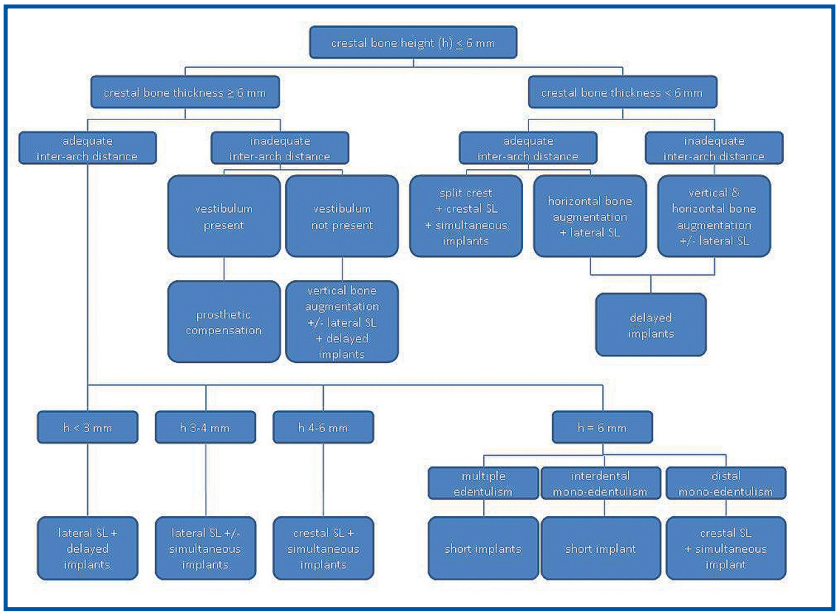

Table 1
Decision making process for the correct implant-supported prosthetic therapeutic indication in the atrophic posterior maxilla with residual crestal bone height ≤ 6 mm.
(h = crestal bone height, SL = sinus lift)

inserted at the same time as bone augmentation procedure. When implant primary stability is not adequate, a two-step surgical procedure is required.

› Residual bone height between 4 and 6 mm allows a more conservative and less invasive approach. Sinus lift with crestal approach and simultaneous implant placement are indicated.

› Residual bone height of at least 6 mm requires a classification in single and multiple edentulism (44).

The correct use of short implants results in high survival rates (3, 9). The strategy of splinting short implants together in order to improve the correct distribution of functional load makes this treatment option not ideal in cases of single distal edentulism. Although the crown / implant ratio was not found to have a significant influence on implant survival, in case of single edentulism it is preferable to choose asurgical protocol combining a sinus lift surgery with a crestal approach and simultaneous placement of longer implants (> 10 mm). In case of a single

FIG. 8
Sinus lift with lateral approach and implant-supported prosthetic rehabilitation with longer crowns may compensate the vertical discrepancy.

FIG. 9
Sinus lift with lateral approach associated with bone augmentation techniques allows a correct and harmonic implant-supported prosthetic rehabilitation in case of increased inter-arch distance and reduced vestibular depth.

edentulous space, a short implant can be inserted in the residual bone, as adjacent teeth provide protection during occlusion. In case of multiple edentulous spaces, rehabilitation with short implants is highly recommended because of its high predictability, lower rate of complications and low morbidity compared to more invasive therapeutic techniques. These preliminary reccomandations derive from ongoing multicenter clinical trials of our department. More long term data are advisable before involving this procedures in clinical practice.

2. Type B: tansverse deficit Considerable resorption in the vestibular-palatal direction may result in an inverse relationship between the bone bases on the horizontal plane (Fig. 10). It is essential to assess the ideal position of the prosthetic crowns and their relationship with the crestal bone. Horizontal prosthetic compensation may lead to overextended crowns, resulting in difficult hygienic maintenance. Moreover, prosthetic compensation may create a horizontal cantilever, increasing lateral forces, especially in partial edentulism. Instead, cross-bite prosthetic rehabilitations show dramatic aesthetic limitations as well as functional consequences: invasion of the lingual area may cause difficulties in phonetics and unintentional cheek biting. In these cases it is essential to correct the skeletal relationship in the horizontal direction, with block grafts or horizontal GBR techniques associated with sinus lift with lateral approach. When the residual crestal bone height is 4 to 6 mm, the split-crest or horizontal bone augmentation can be performed.

3. Type C: vertical deficit Adequate crestal bone thickness with harmonic arch form but increased inter-arch distance are more complex, and the frequently associated decreased vestibulum depth further aggravate the clinical situation.

› When inter-arch distance is moderately increased and vestibulum depth is adequate, it is possible to realize an implant-prosthetic rehabilitation with longer prosthetic crowns, in order to compensate the vertical discrepancy (Fig. 8).

The surgical approach depends on the residual bone height.

› When inter-arch distance is severely increased and vestibulum depth is limited, prosthetic compensation is not possible, since extremely long prosthetic crowns do not correspond to an aesthetically acceptable and hygienically maintainable implant-supported prosthetic rehabilitation. The surgical approach has to restore favorable bone volume and skeletal relationships, in order to obtain a prosthetically-guided rehabilitation with long-term predictability. Three-dimensional alterations of the inter-arch relationship need to be corrected with GBR techniques or block grafts. Bone augmentation techniques can be associated with sinus lift with lateral approach, in order to further increase bone availability for longer implants (Fig. 9).

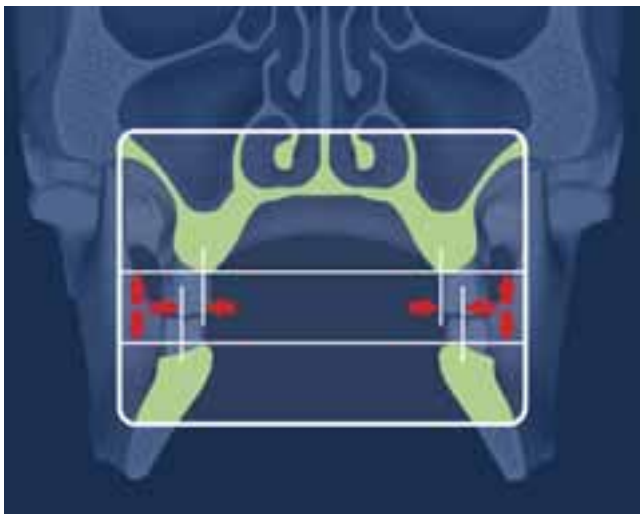

FIG. 10
Tooth loss leads to crestal bone atrophy in the vestibular-palatal direction with opposite vectors, up to inversion of skeletal relationships on the horizontal plane. Image courtesy of ACME Editore (from: Testori T, Wallace SS, Weinstein RL. La chirurgia del seno mascellare. ACME Editore 2005)

4. Type D: combined deficit Tooth loss due to severe periodontal disease, trauma, cystic or neo-plastic diseases contribute to extreme crestal atrophy with extremely compromised anatomical situations. Frequently, the edentulous crestal bone in the posterior maxilla is severly deficient in the vestibular-palatal direction, leading to reverse maxillo-mandibular relationship on the horizontal plane, and in the cranio-caudal direction with significant increase of the vertical inter-arch distance.

Only complex reconstructive interventions may achieve an aesthetically and functionally correct implant-supported prosthetic rehabilitation. The aim is to restore the correct three-dimensional relationship between the ridges, increasing bone thickness and decreasing inter-arch distance and augmenting crestal bone height with block grafts associated with sinus lift procedures with lateral approach (45).

Conclusion

The treatment of the posterior maxillary edentulism requires an accurate pre-operative diagnosis aimed to achieve a prosthetically-guided, functionally and aesthetically ideal rehabilitation.
The diagnostic steps should be performed according to a precise clinical protocol including: general evaluation of the patient health status and expectations; specific extra- and intra-oral evaluation; three-dimensional evaluation of the inter-arch relationship, with particular attention to the skeletal class and inter-arch dimension; three-dimensional clinical and radiographic analysis of the implant site; evaluation of the cost/benefit ratio of each surgical intervention.
Surgical and prosthetic therapeutic alternatives in the implant-supported rehabilitation of the atrophic lateral-posterior maxilla differ mainly in relation to the anatomical situation and the bone availability (Tab. 1). The most predictable solution can be chosen when an accurate individual clinical and instrumental evaluation has been performed.

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