Custom Fabricated Subperiosteal Implants for Sectional Rehabilitation of Severely Atrophic Maxillae: A Technical Note

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Severe atrophy in isolated posterior maxillary sectors poses challenges for dental rehabilitation, especially in partially dentate patients where traditional graftless techniques are unsuitable. This study retrospectively analyzed the outcomes of sectional rehabilitation in 16 consecutive patients with Cawood and Howell class V to VI atrophy treated with 21 custom fabricated subperiosteal implants. Patients were followed for a median of 36 months (interquartile range: 24 to 48). Implant survival and success rates at 1 and 5 years were 95.2%, with minimal complications. Radiological assessments showed no significant bone resorption beneath abutments (mean: 0.18 mm at 1 year). Soft tissue health improved over time, with bleeding on probing affecting 10% of abutments at 6 months and only 2.5% at 4 years. These findings suggest that subperiosteal implants offer a viable graftless solution for sectional rehabilitation in partially dentate patients, combining high survival rates with favorable radiological and soft tissue outcomes. Further studies are needed to confirm long-term effectiveness.

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Innovation

In recent years, subperiosteal implants have garnered renewed interest. In 2017, Mommaerts introduced a new generation of custom manufactured implants, which take advantage of CAD/CAM technology and laser melting.[1] These advances allow for the production of custom-made implants based on computed tomography (CT) scans and diagnostic wax-ups, eliminating the need for direct bone impressions.[2] The design of these implants has undergone significant evolution, informed by stress-shielding simulations and finite element analysis (FEA), with the goal

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of achieving rigid fixation and optimal distribution of masticatory forces on the maxillary resistance pillars.[2,3] As a result, several reports over recent years have documented successful full-arch rehabilitation of severely atrophic maxillae using these implants. The outcomes have been promising, demonstrating an implant survival rate exceeding 95% in the short to medium term.[4-8] One key advantage of these rehabilitations lies in enabling immediate loading for cases of severe bone atrophy without requiring preimplant regenerative surgery.

However, the literature on sectional rehabilitations of the atrophic maxilla with subperiosteal implants remains scarce. To date, there is insufficient evidence supporting the efficacy of subperiosteal implants in such cases, as most of the research focuses on full-arch rehabilitations.[9]

Sectional rehabilitations of the maxilla, though, are frequently requested by patients who do not require treatment of the anterior maxillary sectors or the extraction of the first or molars. In these situations, graftless techniques such as pterygoid or zygomatic implants may not be technically feasible due to the constraints imposed by the anatomical structures of the maxilla.[10] The implant's emergence in these graftless techniques is often limited by the anatomy of the region.[11] In such cases, custom manufactured subperiosteal implants may represent the only graftless alternative to avoid bone regeneration procedures.

For this reason, at the Maxillofacial Surgery Unit of the University of Sassari (Sassari, Italy), rehabilitation with custom-made subperiosteal implants is offered to all patients with Cawood and Howell class V and VI posterior maxillary atrophy who specifically request a graftless, immediate-loading solution, having declined bone regeneration procedures and traditional delayed implant protocols.

As previously described,[7,12-14] all patients undergoing this type of rehabilitation are subjected to cone beam computed tomography (CBCT) of both the maxilla and mandible, with scans featuring a slice thickness of 0.1 to 0.3 mm and covering a wide field of view, including the entire maxilla and cheekbones. The scans are conducted using a radiological template embedded with radiopaque markers, developed based on prosthetic planning. Digital impressions of the dental arches and the radiological template used during the CBCT are also obtained. The Digital Imaging and Communications in Medicine files (DICOM) and stereolithographic (STL) files are then sent to B&B Dental (B&B Dental, San Pietro in Casale, Italy), the company responsible for fabricating the implant.

The CBCT DICOM files are processed using B&B Dental's GS software (B&B Dental, San Pietro in Casale, Italy) to create a 3-dimensional (3D) reconstruction of the bone structure, refined to remove scatter and other artifacts. The STL files of the dental arches and diagnostic wax-up are integrated with the 3D jaw model. The consolidated 3D files are imported into Meshmixer software (Autodesk, San Rafael, CA) for designing the implant, following the surgeon's guidance. While our protocol does not include FEA, the implant design used is based on extensive FEA research previously conducted on the upper maxilla. These studies have demonstrated the efficacy of specific designs in optimizing load distribution and minimizing stress at the bone-implant interface, particularly under oblique and lateral forces.[3,4,15] In addition, the angulation of the abutments is determined through prosthetic planning to align with the functional occlusion. This approach ensures that the abutments align with the long axis of the prosthetic crowns, minimizing stress concentrations and promoting even force distribution across the implant framework.[3,4,15] Each implant features 2 arms with osteosynthesis screw holes—one on the nasomaxillary pillar and the other on the maxillomalar pillar, extending to the anterior face of the zygomatic arch. Screw placement is based on bone thickness, with a minimum of 2 holes per arm. The implants are equipped with integrated multiunit abutments, designed to sit deeper in the alveolar crest slots to reduce basal bone resorption beneath the abutments. The length and orientation of the abutments are customized to align with the diagnostic wax-up and gingival thickness derived from the scans of the dental arches. A cobalt-chrome surgical guide is produced to facilitate the preparation of alveolar crest slots. On the palatal side, abutments are reinforced by a palatal connection with a screw hole, where the underlying bone allows it.

The 3D models of the bones, gums, prostheses, and implants are then reviewed in the B&B Dental GS software for final approval by the surgeon (Fig 1). Once approved, the implants are manufactured using grade V titanium and double laser melting technology (MYSINT100, Sisma, Piovene Rocchette, Italy). The implants undergo sintering at 840 °C for 4 hours and 500 °C for 2 hours to stabilize the titanium and remove porosity without altering dimensions. Abutments are milled with precision using a 5-axis milling machine (Datron D5, Datron, Milford, NH), and the internal threads of the multiunit abutments are crafted as needed. To ensure cleanliness, the implants are thoroughly cleaned with DOWCLENE 1601 (Dow Chemicals Corporation, Midland, MI), an organic acid, and subsequently sterilized. Templates for crest preparation are fabricated from durable cobalt-chrome. In addition, a STL resin model of the maxilla is created

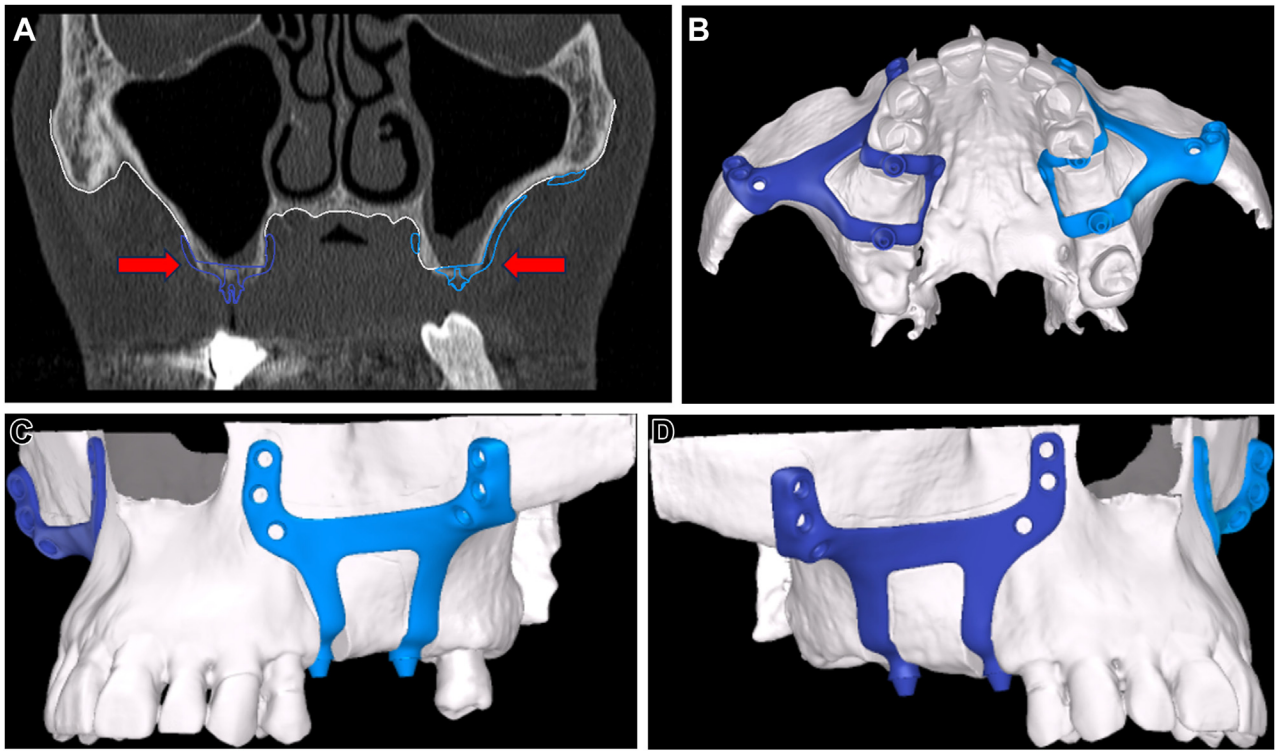

FIGURE 1. Subperiosteal implant virtual planning. *A,* CT scan coronal view showing severe atrophy of the alveolar ridge (*red arrows*). *B,* Subperiosteal implant planning bottom view. *C,* Left subperiosteal implant planning. *D,* Right subperiosteal implant planning. Abbreviations; CT, computed tomography.

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using a 3D printer (Stratasys Objet 30, Stratasys, Eden Prairie, MN) and provided to the surgeon as a reference.

The surgery is carried out under local anesthesia supplemented with superficial intravenous sedation using diazepam. Local anesthesia is administered with articaine containing 1:100,000 adrenaline. Anesthesia of the upper front surgical field is achieved by blocking the infraorbital and zygomatic nerves through an extraoral approach. Intraoral anesthesia is applied to the upper vestibular fornix, with palatal anesthesia achieved by blocking the greater palatine and nasopalatine nerves.

A full-thickness mucosal incision is made along the alveolar crest with 2 releasing incisions at least 5 mm away from the most distal and mesial abutments. The incision is positioned 2 to 3 mm palatally to ensure sufficient keratinized gingiva could be repositioned on the vestibular side of the abutments. A full-thickness flap is raised on both the vestibular and palatal sides. Initial dissection of the maxilla is limited to the alveolar crest to allow for the placement of the crestal preparation template. Slots for the abutment housing are prepared using the template, ensuring they reach the basal bone (Fig 2A). If preparation extends to the sinus membrane, the membrane is carefully preserved or, if perforated, repaired using a porcine-derived collagen membrane (Geistlich Bio-Gide Perio, Geistlich Pharma AG, Wolhusen, Switzerland).

Further dissection is performed to expose the upper maxilla, identify and preserve the infraorbital nerve, and fully detach the nasomaxillary pillar and zygomatic buttress. If needed, the anterior insertions of the masseter muscle are released to facilitate this step. The subperiosteal implant is positioned and its fit verified. Rigid fixation is achieved using grade V titanium osteosynthesis screws (B&B Dental, San Pietro in Casale, Italy) with diameters of 2 mm. Screw lengths range from 10 to 14 mm for the zygomatic buttress, 4 to 6 mm for the nasomaxillary pillar, and 4 to 8 mm for the palate. If adequate torque cannot be achieved, a 2.3 mm diameter safety screw is used. At least 2 screws per pillar are placed to ensure adequate primary stability for immediate loading (Fig 2B).

Once the implant is fixed, the structure is covered with resorbable membranes, cortical laminae, or, when feasible, Bichat's fat pad is transposed to thicken the soft tissue over the vestibular aspect (Fig 2C). The mucosal flap is passivated using periosteal releases and sutured (Fig 2D).

Postoperatively, all patients are prescribed antibiotics (amoxicillin with clavulanic acid, 1 g twice daily for 6 days) and pain management medications. Immediate loading is performed in all cases using a fixed

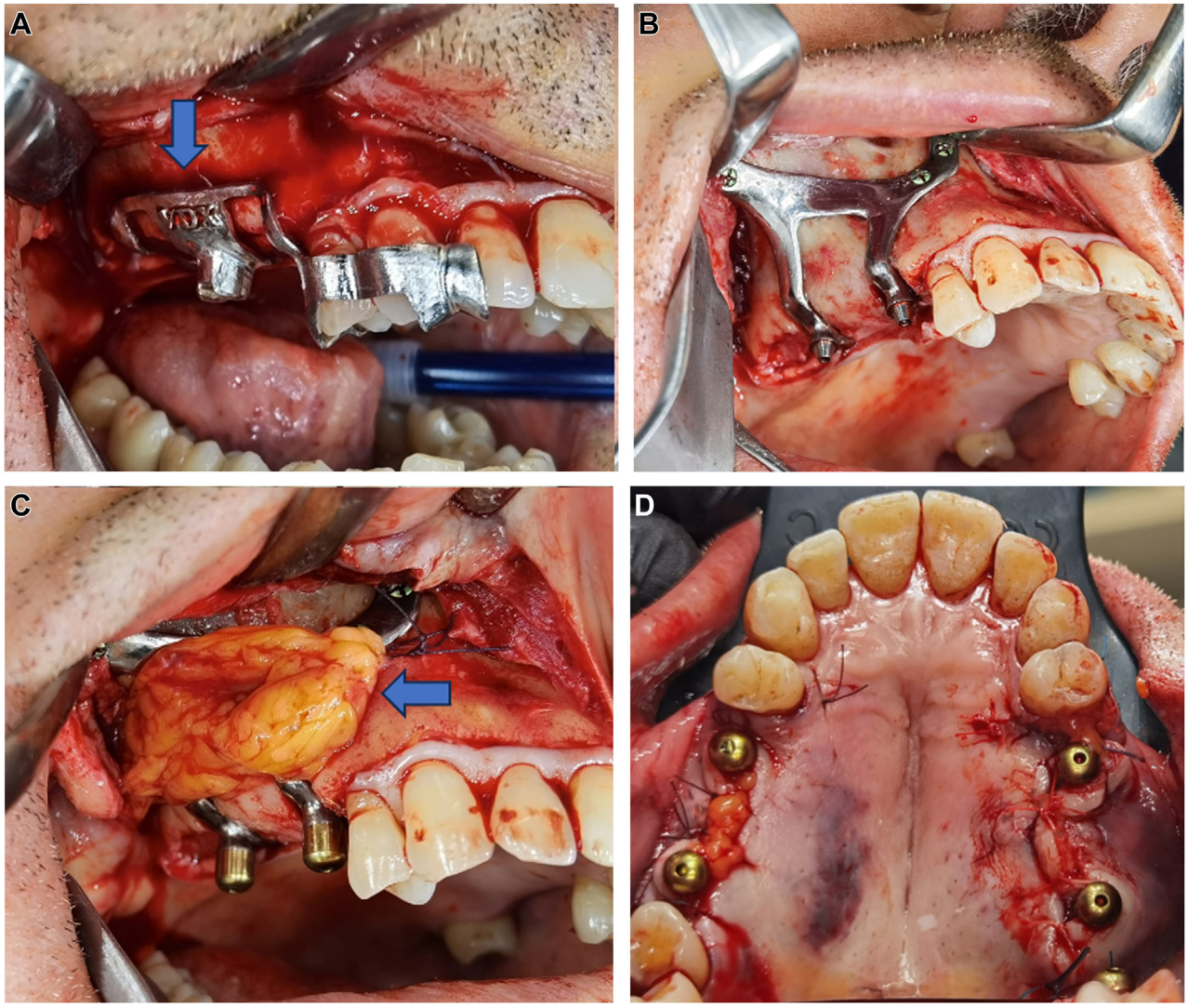

FIGURE 2. Intraoperative views. *A,* Surgical template (*blue arrow*) housed on the alveolar crest for the preparation of the abutment housings. *B,* Subperiosteal implant fixed in position. *C,* Bichat fat pad (*blue arrow*) transposed to cover the implant in order to thicken the soft tissues. *D,* Final suture.

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provisional prosthesis secured to the multiunit abutments. The definitive prosthesis is delivered 6 months postsurgery, after sufficient soft tissue conditioning. Patients are advised to maintain a soft diet for the first 15 days and to avoid hard foods until the final prosthesis was fitted.

Advantages

Custom-manufactured subperiosteal implants for sectional rehabilitation of the atrophic posterior maxilla present key advantages over existing approaches. The most notable benefit is the ability to achieve immediate loading without requiring bone grafting or sinus augmentation, thereby reducing overall treatment time, surgical morbidity, and patient discomfort. Unlike alternative graftless techniques, such as zygomatic and pterygoid implants, which are limited by anatomical constraints, subperiosteal implants can be customized to accommodate complex maxillary morphologies, ensuring a more predictable prosthetic outcome.

Another major advantage is the minimally invasive nature of the procedure compared to traditional full-arch rehabilitations, as it preserves residual dentition and does not necessitate extraction of noncompromised anterior teeth. In addition, the precision afforded by CAD/CAM design allows for optimal implant fit, improving primary stability and minimizing soft tissue irritation.

However, certain trade-offs must be considered. While subperiosteal implants eliminate the need for

regenerative surgery, their fabrication and planning require advanced imaging and digital workflows, which may increase initial costs and logistical complexity. The technique also demands strict adherence to surgical protocols to prevent complications such as mucosal dehiscence or soft tissue inflammation. Despite these considerations, our findings suggest that this approach provides a viable alternative for patients seeking a less invasive, graftless solution while maintaining high implant survival and success rates.

Significance

The use of custom-manufactured subperiosteal implants for sectional rehabilitation of the atrophic posterior maxilla has the potential to offer significant benefits for patient care, surgical practice, and health-care approaches. This technique provides an alternative for patients with severe bone atrophy who are unwilling or unable to undergo traditional bone regeneration procedures or for whom other graftless solutions may not be feasible due to anatomical limitations. By enabling immediate loading and avoiding more invasive surgeries, this approach may reduce treatment timelines and improve patient comfort.

Evidence

Between February 2018 and November 2023, 16 patients with Cawood and Howell class V and VI posterior maxillary atrophy were treated with 21 subperiosteal implants at the University Hospital of Sassari: 7 (43.7%) female and 9 (56.3%) male, mean age of 60.4 ± 6.36 years (range 51 to 73) with a median follow-up duration of 34 [Interquartile range 19 to 54] months (range 12 to 73 months). Rehabilitation was unilateral in 11 (68.7%) cases and bilateral in 5 (31.3%). Table 1 reports a summary of the characteristics of the rehabilitations performed. Ethical approval for the study was obtained from the institutional ethical committee (PG/2023/6411).

Of the 21 subperiosteal implants, 2 (9.5%) were used to rehabilitate the molar region alone, while the remaining 19 (90.5%) restored both the premolar and molar areas. For these latter cases, subperiosteal implants were selected, as it was not feasible to place endosseous implants in the premolar region. In addition, the need to preserve existing teeth or anatomical constraints made distal pterygoid implant placement impossible, necessitating the use of subperiosteal implants.

During the surgeries, no major complications were reported. In one case, the greater palatine artery was inadvertently sectioned during surgical access, but the bleeding was effectively controlled with local hemostasis. In another case, the maxillary sinus membrane was perforated during abutment housing preparation. The perforation was repaired using a porcine-derived collagen membrane (Geistlich Bio-Gide Perio). The average duration of the surgical procedures was 48 ± 8.9 minutes, with a range between 34 and 68 minutes.

In the postoperative period, the most common complication observed was edema, ranging from moderate to severe in all patients. Edema resolved completely within 7 to 10 days. Transient hypoesthesia was observed in 6 cases (28.6% of the implants) in the infraorbital nerve territory and in 2 cases in the zygomatic nerve territories. These sensory deficits resolved fully within 3 months after surgery.

One instance of surgical wound dehiscence occurred, leading to implant infection and mobility, which required implant removal. The single implant loss in this series occurred in a heavy smoker. In this

Table 1. IMPLANTS' CHARACTERISTICS

Characteristic	Number of Implants
Sex	
Male	12 (57.1%)
Female	9 (42.9%)
Intersex	0 (0%)
Age (mean [SD])	60.4 ± 6.36
Smoking status	
Current	4 (19%)
Former	6 (28.6%)
Never	11 (52.4%)
Side	
Left	12 (57.1%)
Right	9 (42.9%)
Number of the abutments	
1	0 (0%)
2	21 (100%)
>2	0 (0%)
Type of the abutments	
Multiunit abutment	20 (95.2%)
Cementable abutment	1 (4.8%)
Position of the abutments	
#4-#6	4 (19%)
#4-#7	3 (14.3%)
#5-#6	1 (4.8%)
#5-#7	11 (52.4%)
#6-#7	2 (9.5%)
Number of screws	
5	4 (19%)
6	12 (57.1%)
7	5 (23.8%)

Abbreviation: SD, standard deviation.

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case, the incision was likely made slightly too palatal, which led to marginal necrosis of the vestibular flap in the postoperative period. It is critical to ensure that the incision remains no more than 2-3 mm palatal, as the palatal mucosa relies on the angiosome of the greater palatine artery for vascular support.[16] Initially, the necrotic mucosa was managed by trimming the tissue and resuturing the wound, but the patient continued smoking, leading to a second wound dehiscence, infection of the surgical site, and eventual implant mobility. The implant was removed, and the surgical site was allowed to heal. After 60 days, the patient underwent reimplantation of a subperiosteal implant. The repositioned implant did not encounter further complications, was successfully loaded, and remains in function 2 years after the second surgery. The implant survival rate at 1 and 5 years was 95.2% (95% confidence interval: 85.3 to 100%) (Fig 3A), while the 1- and 5-year subject survival rate was 93.8% (95% confidence interval: 71.7 to 98.9%). The success rate at 1 and 5 years, based on Albrektsson's criteria,[17] was also 95.2% (95% confidence interval: 85.3 to 100%) (Fig 3B). During follow-up, no implant structure exposures or complications affecting the prosthesis were observed.

Periimplant bleeding on probing (BOP) was assessed at 6 sites around each abutment—mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual—using a four-point scale defined by Mombelli,[18] ranging from 0 (no bleeding) to 3 (heavy, widespread bleeding upon probing). Soft tissue evaluation was performed at 6 months and annually thereafter. At 6 months, 10% of the abutments (4 out of 40) BOP scored as grade 1. At 12 months, 5% of the abutments (2 out of 40) continued to show BOP. The implants supporting these abutments were followed up for 3 and 4 years, respectively. At these time points, only 1 abutment still exhibited BOP, consistently scored as grade 1.

Postoperative control orthopantomography (Fig 4) and CT scans were performed 10 days after surgery, followed by evaluations at 6 months, 1 year, and then annually. No radiological complications were observed, including no signs of sinusitis or issues related to screw positioning. The bone gap beneath the abutment was evaluated by 2 independent reviewers as described by Van Den Borre et al[19] Postoperative CBCT images were stored as DICOM datasets and imported into B&B Dental GS software for segmentation. A predefined threshold for bone was selected to generate a 3D model, which was then refined using semi-automated segmentation in region grow mode. Manual 2D multislice segmentation was performed to ensure meticulous removal of titanium alloy and scatter artifacts. The final models were saved in STL format and prepared for analysis. Surface-based superimposition of the postoperative CT scans was conducted using Geomagic Studio (Geomagic, Morrisville). Scans were aligned through a semi-automated registration process, with initial manual overlap followed by automatic best-fit surface alignment. This process ensured minimal discrepancies between scans for optimal analysis. The resulting data were imported into Gom Inspect Suite (Zeiss, Oberkochen, Germany), where a color-coded model was generated to visualize bone apposition and resorption over time. The model highlighted discrepancies in millimeters between fused images using reference points on the crest, aligned with the abutments. The mean gap observed during the postoperative control at 10 days was 0.13 ± 0.19 mm. Measurements showed no significant differences in bone resorption between postoperative and follow-up values at 1, 2, 3, 4, and 5 years, as detailed in Table 2 and Figure 5. Reliability testing

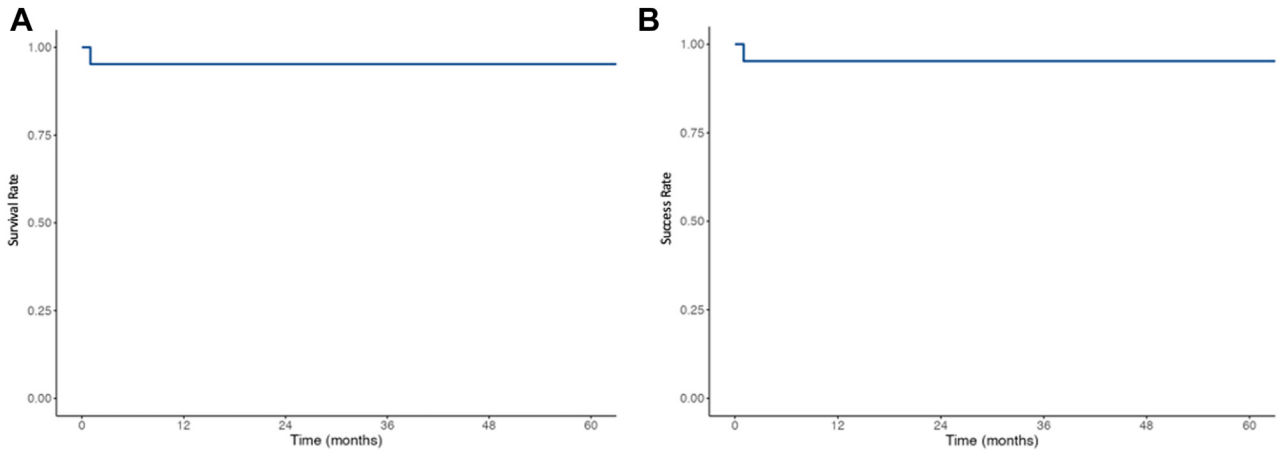

FIGURE 3. *A*, Kaplan-Meier survival curve. *B*, Cumulative success curve.

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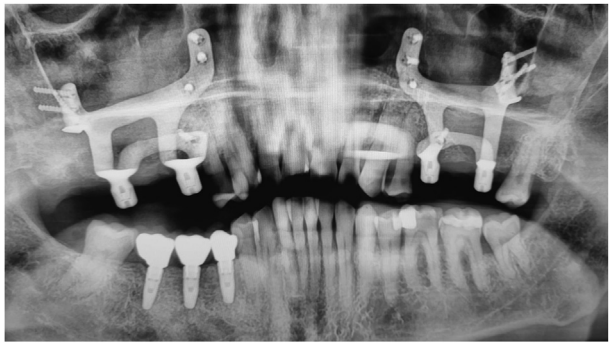

FIGURE 4. Control orthopantomography.

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demonstrated excellent agreement between examiners, with an interexaminer interclass correlation coefficient of 0.89. To assess clinically relevant bone resorption over time, we applied the Albrektsson criteria for endosseous implants, which defines a threshold of >1.5 mm of bone loss in the first year and >0.5 mm/year in subsequent years.

Challenges

In a consensus paper by Herce-López et al,[9] the authors cautioned against the widespread use of custom manufactured subperiosteal implants in cases of partial edentulism due to the limited availability of clinical data supporting their efficacy in such cases. The results of our experience contribute to filling this gap in the literature, providing preliminary evidence that these implants can be effectively and safely employed for sectional rehabilitations, offering a graftless alternative for patients with severe bone atrophy.

The implant survival rate of 95.2% aligns with previously reported rates for subperiosteal implants in full-arch rehabilitation,[5-9] underscoring their potential reliability in sectional applications. However, recent literature highlights the evolving landscape of subperiosteal implants and underscores the variability in outcomes reported across studies. A systematic review by Anitua et al[20] evaluated the performance of modern additively manufactured subperiosteal implants, reporting a short-term implant survival rate of 97.8%, albeit with a noticeable prevalence of soft-tissue-related complications, including partial implant exposure (25.6%) and persistent soft tissue infections (5.3%). Similarly, Łoginoff et al[21] discussed the historical evolution and contemporary advancements in subperiosteal implants, emphasizing the improvements brought about by CAD/CAM and additive manufacturing in terms of precision and fit. However, the authors highlighted persistent challenges, such as long-term durability and soft tissue health, particularly in anatomically complex cases. These findings contrast with our results, which demonstrate a high implant survival rate of 95.2% and minimal complications over a longer follow-up period, likely reflecting the careful patient selection and specific surgical techniques employed in our study. Nevertheless, these discrepancies underscore the need for extended follow-up studies and multicenter analyses to confirm the long-term effectiveness and refine the clinical application of these implants.

The exposure of the implant structure over time is one of the most frequently reported complications in

Table 2. BONE RESORPTION UNDER THE ABUTMENTS. STATISTICAL ANALYSIS RESULTS

Observation Time	Sample Size (n, Abutments)	Bone Gap (mm) Mean ± SD	*P* Value*	Implants Exceeding Clinically Significant Bone Loss (%)
T0 vs T1	40	0.13 ± 0.2 vs 0.18 ± 0.15	.2	0 (0%)
T0 vs T2	28	0.15 ± 0.12 vs 0.18 ± 0.11	.3	0 (0%)
T0 vs T3	20	0.23 ± 0.18 vs 0.22 ± 0.1	.2	0 (0%)
T0 vs T4	12	0.20 ± 0.11 vs 0.22 ± 0.14	.2	0 (0%)
T0 vs T5	4	0.2 ± 0.17 vs 0.21 ± 0.18	.1	0 (0%)

Abbreviation: SD, standard deviation.

* Student's *t*-test.

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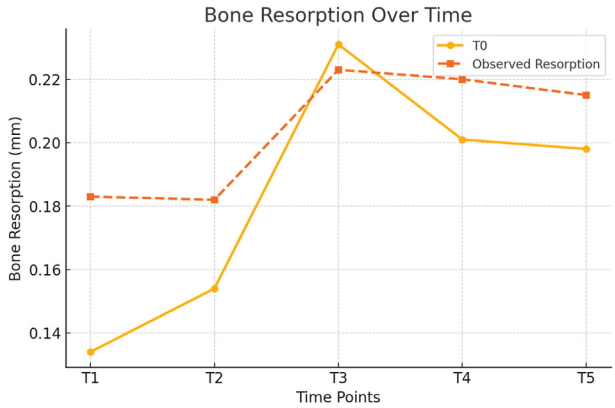

FIGURE 5. Graphical representation of bone resorption over time. The solid line represents the baseline bone level at T0, while the dashed line indicates the observed resorption at different follow-up time points (T1-T5). The Y-axis shows bone resorption in millimeters (mm), and the X-axis represents the follow-up time points. The baseline value at T0 may vary across different time points because only the abutments that remained in function at a given follow-up were included in the analysis for that time point. This ensures consistency in comparisons over time.

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the literature, with prevalence rates ranging from 24% to over 60%,[7-9,22,23] significantly impacting implant success rates. In our series, no implant structure exposures were observed. This outcome was achieved by adopting specific technical measures that should be carefully considered. During implant planning, particular attention should be given to smoothing the transition angles between the crestal portion of the implant supporting the abutments and the vertical arms to prevent soft tissue pressure points. The abutment must be embedded within the crest and not merely rest on it, even in areas beneath the maxillary sinus where bone thickness may be minimal. The entire thickness of the implant at the crestal level should be housed within the bone rather than positioned atop it. In addition, the use of Bichat's fat pad or resorbable membranes to thicken the soft tissues over the vestibular aspect of the implant plays a crucial role in preventing exposure. The mucosal incision is made 2 to 3 mm palatal to ensure that an adequate amount of keratinized gingiva is repositioned on the vestibular side of the abutments. Beyond preventing exposure, this approach enhances the mucosal seal around the implants, reducing the risk of chronic inflammation and, consequently, BOP. In this series, soft tissue health around the abutments was satisfactory (Fig 6), with only a 10% of abutments exhibiting mild BOP (grade 1) at 6 months. Over time, BOP scores improved, with only 1 abutment showing persistent grade 1 BOP at the 3- and 4-year follow-up.

Radiological assessment revealed no signs of sinusitis or screw-related complications, and the observed bone resorption beneath the abutments was not statistically significant at any follow-up interval. This approach is consistent with findings reported for full-arch rehabilitations with subperiosteal implant,[7,14,19,24] or endosseous implants placed in native bone.[25] To ensure long-term stability and minimize resorption, it is essential to remove any residual alveolar bone, if present, so that the abutment rests directly on the basal bone. Basal bone is inherently more stable and less prone to resorption over time,[26] offering a durable foundation that supports the implant's integrity and functionality.

A key limitation not only of this study but of all current research on subperiosteal implants is the absence of standardized success criteria. Unlike endosseous implants, which have well-defined benchmarks such as the Albrektsson criteria, subperiosteal implants lack universally accepted parameters for long-term evaluation. In this study, we used the Albrektsson thresholds as a reference for assessing bone resorption, but we acknowledge that these criteria were developed for endosseous implants and may not fully apply to subperiosteal designs. This highlights the urgent need for dedicated success criteria for subperiosteal implants, incorporating parameters such as bone stability, soft tissue health, and implant longevity. Establishing such criteria will be crucial to improving the comparability and clinical relevance of future studies in this field. Furthermore, another important limitation of our series is the relatively short follow-up period, with an average duration of 36 months and a maximum of 73 months. While these data provide valuable preliminary insights, they do not allow for definitive conclusions about the long-term success and stability of the implants, particularly beyond 10 years. Historically, subperiosteal implants fabricated using direct casts models, were associated with significant complications. These included progressive bone resorption, epithelial invagination around the abutments, and the development of oroantral fistulas, all of which severely undermined implant survival rates. These

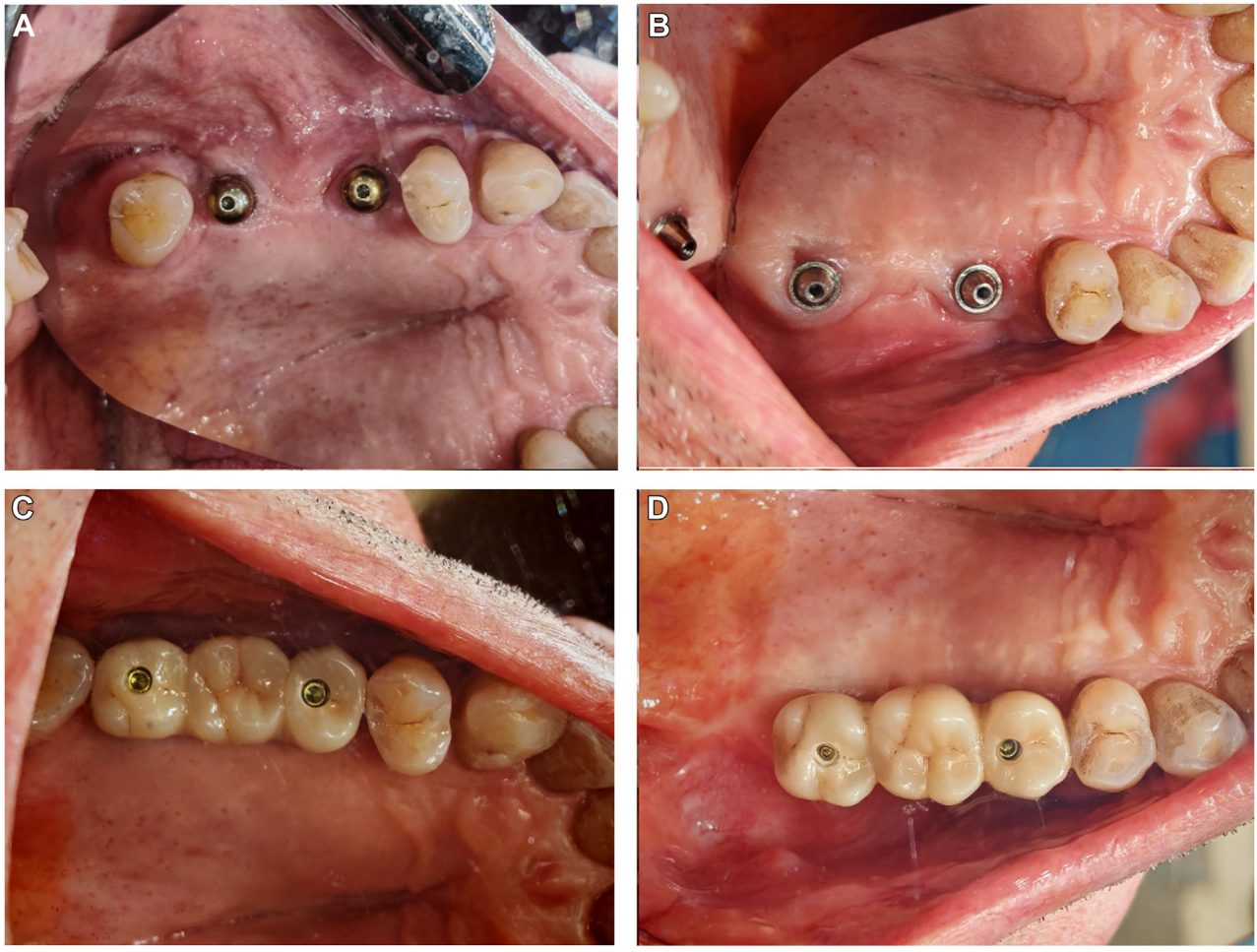

FIGURE 6. Soft tissue control 6 months after surgery. *A*, Left side. *B*, Right side. Final prosthesis 6 months after surgery. *C*, Left side. *D*, Right side.

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complications often became more pronounced over extended periods, with failure rates escalating beyond the 10-year mark.[27] Future studies with follow-ups exceeding 10 years will be crucial to validate whether these advancements translate into sustained success rates comparable to or exceeding those of alternative implant techniques. Until such data become available, the findings of this study should be considered preliminary but promising, providing a foundation for further exploration of this modern approach.

Furthermore, the foremost limitation which limits the level of evidence of our experience is the relatively small sample size of 16 patients with 21 subperiosteal implants. While the findings provide valuable preliminary insights, the small cohort limits the generalizability of the results. This reflects the niche nature of the patient population and the specificity of the surgical approach, which are not widely applied or documented in the literature. To date, no published series has focused exclusively on this patient subgroup, making this study an initial exploration of a potential solution for these challenging cases. Furthermore, the retrospective nature of the study may introduce inherent biases related to patient selection and data collection. A potential limitation of this study is the inherent selection bias introduced by focusing on a highly specific patient population—those with severe sectoral maxillary atrophy who explicitly declined bone regeneration procedures and traditional implant approaches—reflecting a subset with unique clinical needs and preferences. Finally, a limitation of this study is the variable duration of follow-up among patients, which could influence the interpretation of time-dependent outcomes such as bone resorption and implant survival. While we have applied time-to-event analyses (Kaplan-Meier) to account for censored observations and ensure a standardized evaluation of implant survival and clinically significant bone loss, variations in follow-up duration may still introduce potential bias.

Time

The widespread adoption of custom-manufactured subperiosteal implants for sectional rehabilitation of the atrophic posterior maxilla is likely to follow a gradual trajectory, influenced by advancements in technology, accumulation of long-term clinical evidence, and evolving surgical practices. While CAD/CAM technology and additive manufacturing have resolved many of the issues associated with earlier generations of subperiosteal implants, such as imprecise fit and high rates of complications, the long-term success of modern implants remains to be fully validated. Historical data from older-generation implants revealed significant complications, particularly after 10 years, including progressive bone resorption, soft tissue issues, and implant failures. To ensure this new generation achieves widespread acceptance, further studies with follow-ups exceeding 10 years are essential to confirm their durability and effectiveness over extended periods. If supported by robust evidence and accompanied by standardized protocols and surgeon training, these implants could transition from niche innovation to mainstream clinical practice within the next 5 to 10 years.

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