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Comprehensive protocol for custom subperiosteal implants in atrophic maxilla: Series of 6 clinical cases

Protocolo integral para implantes subperiósticos personalizados en maxilares atróficos: Serie de 6 casos clínicos

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ABSTRACT: The aim of this study was to define a comprehensive protocol (planning, design, placement, prosthetic rehabilitation) for customized subperiosteal implants in atrophic maxilla. A descriptive case series study was conducted with a purposive sample of six patients who underwent surgery with customized subperiosteal implants. Rigorous inclusion and exclusion criteria were established. Clinical, radiographic, and digital data were collected, recorded in Windows Excel, and analyzed with IBM SPSS software, version 27. The variables analyzed included demographic characteristics, preoperative patient preparation, planning, design and fabrication of the subperiosteal implant, surgical procedure, prosthetic rehabilitation, and follow-up. The results showed that 83.3 % of patients were female, with a mean age of 65.5 years. Most exhibited bone atrophy classified as Class V and VI according to Cawood and Howell. All implants were fabricated from Grade V Ti using direct laser sintering, with a monoblock design in 83.3 % of cases. Surface treatment techniques such as sandblasted, large grits and acid etched (SLA) were employed to enhance osseointegration. The mean duration of surgery was 64.1 minutes, with an average follow-up period of 18.33 months. A 100 % implant survival rate was reported, though minor complications such as mucositis and structural exposure were observed. Customized subperiosteal implants represent an effective and less invasive solution for patients with severe bone atrophy. Implementing a comprehensive protocol improves quality of life and reduces treatment time, establishing these implants as a viable alternative to more complex bone regeneration techniques. Further research is needed to standardize these procedures and optimize clinical outcomes.

KEY WORDS: Subperiosteal implants, atrophic maxilla, prosthetic rehabilitation, digital techniques.

INTRODUCTION

Subperiosteal implants (SPI) are a significant alternative in dental rehabilitation, placed between the periosteum and the residual alveolar bone. These implants initially gained acceptance but saw a decline in popularity by the late 1970s with the increasing use of endosseous implants, as proposed by Branemark. Factors contributing to this decline included the need for dual surgical interventions, complexity in manufacturing and implant placement, and a high rate of failure and complications, such as fitting issues and mobility during mastication (Gellrich *et al*., 2017; Cerea & Dolcini, 2018).

In recent years, there has been renewed interest in SPIs, driven by the digital revolution in dentistry. Technologies such as computed tomography and intraoral scanners, along with the development of Computer-Aided Design (CAD) and computer-aided manufacturing (CAM) software, have facilitated the customization of SPIs. Additionally, advanced

techniques like stereolithography and direct metal laser sintering (DMLS) have enhanced the precision and reproducibility of these implants (Cerea & Dolcini, 2018; Strappa *et al*., 2022).

The materials used for SPIs have also evolved. Previously, Vitallium alloy was commonly used, though it had limitations in terms of osseointegration. Today, Grade V titanium (Ti6Al4V) is preferred, offering improved mechanical and biological properties that promote more effective osseointegration bridges between the implant and the underlying tissue (González *et al*., 2018).

The loss of alveolar bone support following tooth extraction is a critical challenge in dental rehabilitation, especially for edentulous patients. This phenomenon, which includes vertical and horizontal resorption of the maxilla (Rancaño-Álvarez *et al*., 2019), complicates the placement of conventional dental implants, often leading to significant complications due to insufficient bone (Pjetursson *et al*., 2012; Spencer, 2018). Although bone regeneration techniques have been proposed, these procedures are invasive and require a prolonged recovery time (Polis-Yanes *et al*., 2017; Chiapasco *et al*., 2018).

In this context, SPIs offer an alternative approach that avoids the need for bone grafts and allows for immediate functional rehabilitation in a single surgical session (Mommaerts, 2017; Ayhan & Cankaya, 2023). Despite technological advances in the use of SPI, current literature highlights a lack of standardized or comprehensive protocols for their placement, underscoring the need for further research in this field.

The objective of this case series is to define a comprehensive protocol encompassing the planning, design, surgical procedure, prosthetic rehabilitation, and follow-up of customized subperiosteal implants in atrophic maxillae. This protocol aims to optimize clinical outcomes and contribute to existing knowledge on the use of SPIs, offering a clear guide for their implementation in clinical practice.

MATERIAL AND METHOD

An observational, descriptive case series study was designed involving patients with severe maxillary bone atrophy, classified as Cawood and Howell types V and VI, who were treated with customized subperiosteal implants. These implants were designed in collaboration with a single company, CPMH Digital (Brasilia, Brazil). All patients provided informed consent for the surgical intervention and participation in the study. The study was approved by the ethics committee of the Dr. José Gregorio Hernández General Hospital of the West and was conducted in full compliance with the 1975 Declaration of Helsinki on patient rights (2008 revision).

A total of six patients (one male and five female) between the ages of 53 and 68 years (mean age of 60.5) were enrolled in the study. All six patients had a history of severe bone loss in the maxilla; in one case, this was due to a partial maxillary resection and soft tissue reconstruction, resulting in free end edentulism. All patients had requested fixed implant-supported dental prostheses, as bone reconstruction through conventional techniques was either absent or deemed impossible.

Comprehensive Protocol for Customized Subperiosteal Implants

Phase 1: Patient Selection Criteria and Preoperative Preparation (Table I).

Eligibility was based on the following inclusion criteria:

a) Complete or partially edentulous maxilla with significant maxillary bone resorption.
b) Maxillary bone atrophy classified as Cawood and Howell Class V–VI.
c) Patients unable or unwilling to undergo other procedures.

Exclusion criteria included:

d) Systemic diseases or drug therapies that contraindicate surgery (e.g., immunocompromised states, uncontrolled diabetes mellitus, bone metabolic diseases, or bisphosphonate treatment).
e) Ongoing chemotherapy or radiotherapy.
f) Edentulous or partially edentulous maxilla allowing for standard-sized implants.

A thorough diagnosis included occlusal positioning (Fig 1A), a standard tessellation language (SLT) file of intraoral anatomy, and computed tomography (CT). Accurate impressions of the partially or fully edentulous arches were taken, followed by a digital diagnostic wax-up to define the screw-retained prosthesis over the subperiosteal implant's mini-pillars. If the patient used a full removable prosthesis, it was duplicated for the digital diagnostic wax-up.

Table I. Patient selection criteria and preoperative preparation.

Case	Age	Sex	Previous regeneration and/or alternative techniques for rehabilitation	Number of remaining teeth in maxilla	Classification of Cadwell and Howell	Location of the bone atrophy	Cause of bone defect
Nº1	59	F	NO	1	Class V	Maxillary	Idiopathic bone atrophy
Nº2	53	F	NO	Completely edentulous	Class VI	Maxillary	Idiopathic bone atrophy
Nº3	66	F	NO	4	Class VI (maxilla former)	Maxillary área former	Maxillary defect oncological (maxillectomy)
Nº4	55	F	Conventional implants	5 / conventional implants	Class V	Maxillary	Bone atrophy due to periodontal disease
Nº5	62	F	NO	5	Class V	Maxillary	Idiopathic bone atrophy
Nº6	68	M	NO	2	Class V	Maxillary	Idiopathic bone atrophy

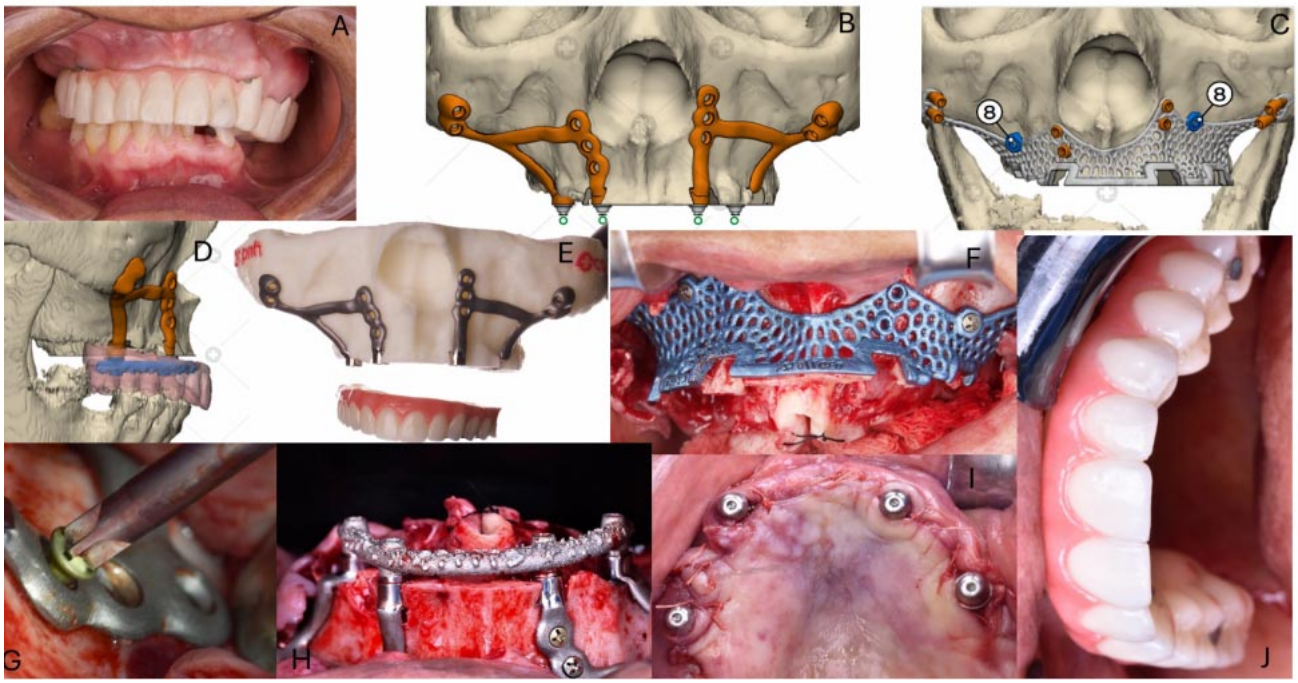

Fig. 1. Case 1: Subperiosteal Implant Placement Protocol. A) Initial occlusal position. B, C, D) Digital planning and design of the subperiosteal implant (ISP). E) Use of a stereolithographic model to verify ISP fit. F) Surgical cutting guide fixed with 2.0 screws. G, H) ISP placement. I) Tissue synthesis with 4.0 Vicryl. J) Immediate loading of provisional prosthesis.

Phase 2: Planning, Design, and Fabrication of the Subperiosteal Implant (Table II).

Customized implants were designed and manufactured by CPMH Digital. Digital Imaging and Communications in Medicine (DICOM) data from CT scans (axial slices no more than 2 mm) reconstructed the patient's bone anatomy, saved in an STL file. This STL was combined with digital scans and diagnostic wax-up STL to create a complete virtual model. From this model, the structure was designed, typically in one or two pieces, to embrace the alveolar ridge and extend towards the zygomatic maxillary, nasomaxillary, and palatal buttresses. The structure was typically secured with 11 to 13 osteosynthesis screws of 2.0 diameter in areas of greater bone density.

Table II. Planning, design and manufacturing of the subperiosteal implant.

Case	Manufacturing technique	Implant material	Fixing system / Number of screws	Location of subperiosteal implant	Subperiosteal implant design	Number of pillars or connections
Nº1	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	11 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	1-piece structure (monoblock)	4 minipilares
Nº2	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	11 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	1-piece structure (monoblock)	4 minipilares
Nº3	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	19 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	2-piece structure (dual)	4 minipilares
Nº4	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	11 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	1-piece structure (monoblock)	4 minipilares
Nº5	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	13 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	1-piece structure (monoblock)	4 minipilares
Nº6	Sintering / Treated with SLA	Ti grade V (TI-6-AI-4V)	11 tornillos de osteosíntesis (Ø2.0mm)	Maxillary	1-piece structure (monoblock)	4 minipilares

The structure included four conical mini pillars (0.6 mm to 2.0 mm in length, based on mucosal thickness) with an internal thread for multiunit connections or the bar. Upon surgeon approval, the SPI structure was refined and smoothed. A surgical guide was designed for osteotomy and screw reference drilling. The SPI was then manufactured through Grade V titanium micro-powder sintering (Ti-6-Al-4V), treated with sandblasting, large grits, and acid etched (SLA), followed by decontamination and sterilization. Additionally, a stereolithographic model of the patient's bone structure was provided.

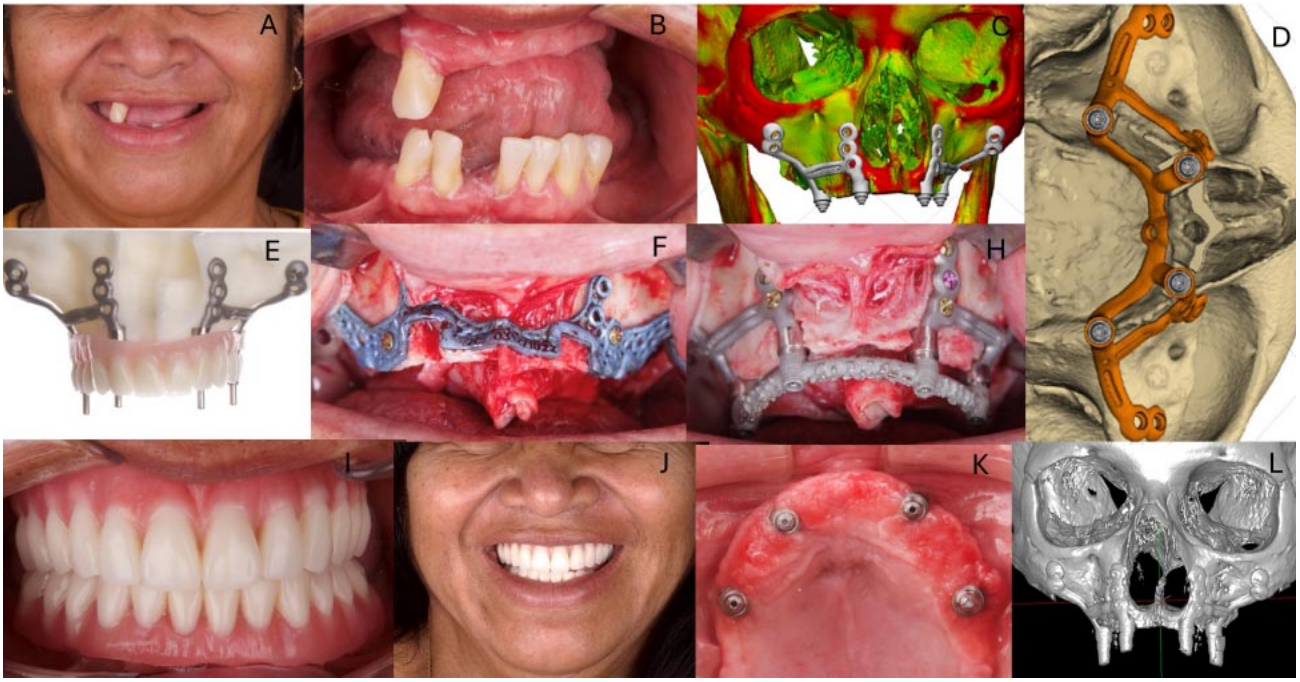

Fig. 2. Case 2: Subperiosteal Implant Placement Protocol. A) Initial smiling photograph. B) Initial occlusal position. C, D) Digital planning and design of the customized subperiosteal implant (SPI). E) Use of a stereolithographic model to verify SPI fit. F) Surgical cutting guide secured with 2.0 screws. H) Placement of the SPI. I) Immediate loading with a bimaxillary provisional prosthesis. J) Final smiling photograph. K) Postoperative complications, showing mucositis. L) Postoperative computed tomography scan.

Phase 3: Surgical Procedure (Table III).

The detailed surgical protocol for subperiosteal implant placement can be performed under conscious sedation with local anesthesia or general anesthesia. A surgical assistant monitored time from anesthesia to final suturing.

a) Patient Preparation: The patient was prepared under strict aseptic protocols. A 3D stereolithographic model was used to verify implant adaptation and ensure adequate subperiosteal elevation.

b) Anesthesia: Local anesthesia with 2 % lidocaine and 1:100,000 epinephrine was administered for effective anesthesia and bleeding control.

c) Incision and Flap: A planned incision preserved keratinized gingiva, allowing the pillars to be surrounded by this gingiva after suturing. A crestal incision was made in the edentulous area with broad posterior releases. A full-thickness flap was elevated across the bone surface receiving the subperiosteal implant, including the palatal region.

d) Implant Placement: If necessary, remaining teeth or conventional implants were removed before placing a surgical guide fixed with at least two screws from the 2.0 system. This guide facilitated precise removal of the residual alveolar ridge, easing the adaptation and descent of the subperiosteal implant towards the bone crest, particularly at the angle between the structure and prosthetic cylinders, to prevent potential future complications, such as implant exposure.

f) Verification and Adjustment: After implant placement, the fit and stability were checked to ensure proper positioning and functionality.

g) Tissue Synthesis: Flaps were repositioned and sutured with Vicryl 3.0/4.0, ensuring the pillars were surrounded by keratinized gingiva.

Phase 4: Prosthetic Rehabilitation (Table IV).

The provisional prosthetic approach was customized to each case, designed flat or convex to avoid debris accumulation between the prosthesis and soft tissue. After the procedure, the provisional prosthesis was either relined and perforated or printed in PMMA or acetal. The subperiosteal implants were loaded immediately with these provisional prostheses, secured with screws to the structure's multiunit connection cylinders. It was crucial to ensure that the prosthesis did not compress the surgical wound, and it was used for an extended period exceeding four months.

Table III. Surgical procedure.

Case	Placement date	Mean surgery time (min)	Incision type	Metallic bone reduction surgical guide	Screw length (mm)
Nº1	14.04.23	65	Crestal incision	YES	5 mm – 8 mm
Nº2	21.07.23	60	Crestal incision	YES	5 mm – 10 mm
Nº3	08.09.22	70	Crestal incision	YES	5 mm – 9 mm
Nº4	15.05.24	55	Crestal incision	YES	5 mm – 12 mm
Nº5	27.05.21	75	Crestal incision	YES	8 mm
Nº6	12.04.23	60	Crestal incision	YES	5 mm – 10 mm

Table IV. Prosthetic rehabilitation.

Case	Typo of rehabilitation	Inmediate provisional rehabilitation	Definitive rehabilitation	Prosthetic connection type
Nº1	Maxillary / Full Arch	Heat cured acrylic	Hydrib acrylic metal with titanium bar	Screwed / Multiunit
Nº2	Maxillary / Full Arch	PMMA	N/A	Screwed / Multiunit
Nº3	Maxillary / Full Arch	Heat cured acrylic	N/A	Screwed / Multiunit
Nº4	Maxillary / Full Arch	Acetal	N/A	Screwed / Multiunit
Nº5	Maxillary / Full Arch	Heat cured acrylic	Hydrib acrylic metal with titanium bar	Screwed / Multiunit
Nº6	Maxillary / Full Arch	Heat cured acrylic	N/A	Screwed / Multiunit

Phase 5: Follow-up, Complications, and Implant Survival (Table V).

Post-surgery, patients followed a postoperative regimen, including clinical check-ups at 7, 15, 30, and 45 days. Sutures were removed at 15 days, and the provisional prosthetic structure was checked. Follow-up was continued every six

Table V. Follow-up and complications.

Case	Follow-up time (months)	Complication	Implant survival
Nº1	16	mucositis	100 %
Nº2	13	N/C	100 %
Nº3	23	N/C	100 %
Nº4	12	N/C	100 %
Nº5	39	Exposure of the structure without functional impediment or aesthetic	100 %
Nº6	16	N/C	100 %

N/C No Complication

months to prevent biological and mechanical complications, with long-term postoperative CT scans to verify implant and screw positioning. Immediate complications included pain and inflammation within two postoperative weeks, while delayed complications, such as infections, mucositis, implant exposure, or fractures of the prosthesis or structure, could occur up to six months post-surgery.

RESULTS

The study included six patients, of whom 83.3 % were women (n=5) and 16.7 % were men (n=1), with an age range between 53 and 68 years, a mean age of 60.5 years, and a standard deviation of 5.958.

Regarding regenerative surgeries, 83.3 % of the patients had not received previous treatments, while 16.7% had undergone prosthetic rehabilitation with conventional implants. As for the remaining teeth in the maxilla, most cases had between 1 and 5 teeth remaining, classified as partially edentulous maxilla, with one case of total edentulism.

The classification of maxillary atrophy according to Cawood and Howell revealed that 66.7 % of patients presented with class V atrophy, while 33.3 % were class VI. Bone atrophy was predominantly located in the maxilla (83.3 %), with a single case in the anterior maxillary area. The causes of bone defect were mainly attributed to idiopathic bone atrophy (66.6%), followed by atrophy associated with periodontal disease and one case of an oncologic maxillary defect.

All implants used were grade V Ti, manufactured through sintering and treated with SLA. In terms of fixation, most patients required 11 screws (66.7 %), while others required 13 and 19 screws. For implant design, 83.3 % of cases used a monoblock structure, and 16.7 % had a two-piece structure. A surgical cutting guide was digitally designed in all cases, and anesthesia was administered equally between conscious sedation with local anesthesia and general anesthesia.

The average surgery time was 64.1 minutes, with a range of 55 to 75 minutes. All incisions were crestal, and a metal bone reduction surgical guide was used in all cases. Screw lengths varied from 5 mm to 12 mm. Immediate provisional rehabilitation was performed for all patients, and the prosthetic connection was a screw-retained multi-unit in all cases. The average follow-up period was 18.33 months, with a range of 12 to 39 months. Complications were reported in 33.3 % of patients, including one case of structural exposure without functional or aesthetic impairment and one case of mucositis. However, implant survival was 100% in all cases analyzed.

DISCUSSION

Dental rehabilitation in severely atrophic maxillae presents a significant challenge for oral and maxillofacial surgeons. Subperiosteal implants have emerged as an effective alternative, enabling the placement of immediate prostheses in patients unsuitable for bone regeneration techniques (Nazarian, 2014; Cerea & Cankaya, 2018; Ângelo *et al*., 2020; Marconcini *et al*., 2023). This study confirms that customized subperiosteal implants are feasible in this context, especially for patients with severe bone resorption.

The findings indicate that idiopathic bone atrophy was the most common cause (66.6%), followed by periodontal disease and oncologic defects. This pattern aligns with previous reviews that highlight bone atrophy as the primary reason for the implantation of these devices (Anitua *et al*., 2024). The literature suggests that subperiosteal implants are particularly suitable for patients with edentulous ridges classified as Class V and VI per Cawood and Howell (Chamorro-Pons *et al*., 2021; Korn *et al*., 2022; Onicaˇ *et al*., 2024).

The mean age of patients in our study was 60.5 years, consistent with previous data suggesting a range of 60 to 67.8 years for these procedures (Nemtoi *et al*., 2022). This reinforces the importance of considering age as a selection criterion for subperiosteal implant rehabilitation.

Placement protocols have evolved toward digital workflows, optimizing healing and improving success rates. However, a standardized protocol has not yet been established in the literature, underscoring the need for a comprehensive approach to planning and executing these procedures (Gellrich *et al*., 2017; Roy *et al*., 2023; ?oginoff *et al*., 2024).

The Ti6Al4V alloy is currently preferred for its superior mechanical and biological properties (Dimitroulis *et al*., 2023). In our study, 100% of implants were manufactured with this alloy, aligning with current research trends. Although sparsely addressed in the literature, implant surface treatment has shown that rough surfaces promote osseointegration (Mommaerts, 2019; Nemtoi *et al*., 2022). In our case, we used an SLA treatment, which has shown promising results for bone integration (Lackington *et al*., 2022).

For implant design, it is crucial to consider the option of designing two independent frames or pieces to facilitate implant insertion during the surgical procedure. Subperiosteal structures with multiple prosthetic connections offer greater long-term stability. The literature also indicates that immediate loading of implants can accelerate functional recovery and improve patient quality of life (Chamorro-Pons *et al*., 2021; Herce-López *et al*., 2024; Onicaˇ *et al*., 2024). In our view, it is essential to avoid abrupt transitions and sharp angles in areas between the subperiosteal structure and prosthetic connections, as they are associated with an increased likelihood of implant exposure.

Procedures can be performed under local anesthesia, preferably combined with conscious sedation or general anesthesia (Ângelo *et al*., 2020; Chamorro-Pons *et al*., 2021; Herce-López *et al*., 2024). In this study, three patients received local anesthesia with sedation and three received general anesthesia. The crestal incision used allowed for adequate exposure of the maxillary bone, aligning with best practices (Mommaerts, 2017; Herce-López *et al*., 2024). The average surgery time in our study was 64.1 minutes, which is favorable compared to other studies (Nemtoi *et al*., 2022; Korn *et al*., 2022). The use of metallic surgical guides also contributed to the precision of the procedure; in contrast, few studies employ metallic surgical guides (Onicaˇ *et al*., 2024).

Our study reports a 100% implant survival rate over a follow-up period of up to 3 years, contrasting with previous studies showing variable survival rates (Mounir *et al*., 2018; Mangano *et al*., 2020). Complications observed, mainly related to soft tissues, such as partial structural exposure, did not seem to affect short-term functionality (Van den Borre *et al*., 2023).

CONCLUSION

Subperiosteal implants have advanced significantly, offering an effective option for patients with extreme bone atrophy, where conventional implants are not viable. Their customization and improved design have increased their applicability. Although our study sample is limited, the 100% success rate over a 1 to 3-year follow-up suggests that they provide a durable solution for dental rehabilitation. It is essential to evaluate their long-term success, considering patient stability and satisfaction.

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Ethical Approval: The study was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from each subject involved in the study.

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RESUMEN: El objetivo de este estudio fue definir un protocolo integral (planificación, diseño, colocación, rehabilitación protésica) para implantes subperiósticos personalizados en maxilares atróficos. Se realizó un estudio descriptivo de serie de casos con una muestra intencional de seis pacientes que se sometieron a cirugía con implantes subperiósticos personalizados. Se establecieron criterios de inclusión y exclusión rigurosos. Se recolectaron datos clínicos, radiográficos y digitales, que se registraron en Windows Excel y se analizaron con el software IBM SPSS, versión 27. Las variables analizadas incluyeron características demográficas, preparación preoperatoria del paciente, planificación, diseño y fabricación del implante subperióstico, procedimiento quirúrgico, rehabilitación protésica y seguimiento. Los resultados mostraron que el 83,3 % de los pacientes fueron mujeres, con una edad media de 65,5 años. La mayoría presentó atrofia ósea clasificada como Clase V y VI según Cawood y Howell. Todos los implantes fueron fabricados a partir de Ti Grado V mediante sinterización directa por láser, con un diseño monobloque en el 83,3 % de los casos. Se emplearon técnicas de tratamiento de superficie como el pulido con chorro de arena, el grabado con ácido y el grabado con granalla gruesa (SLA) para mejorar la osteointegración. La duración media de la cirugía fue de 64,1 minutos, con un período de seguimiento medio de 18,33 meses. Se informó una tasa de supervivencia del implante del 100 %, aunque se observaron complicaciones menores como mucositis y exposición estructural. Los implantes subperiósticos personalizados representan una solución eficaz y menos invasiva para pacientes con atrofia ósea grave. La implementación de un protocolo integral mejora la calidad de vida y reduce el tiempo de tratamiento, lo que establece estos implantes como una alternativa viable a las técnicas de regeneración ósea más complejas. Se necesita más investigación para estandarizar estos procedimientos y optimizar los resultados clínicos.

PALABRAS CLAVE: Implantes subperiósticos, maxilar atrófico, rehabilitación protésica, técnicas digitales.

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