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Clinical Paper
Reconstructive surgery

Three-dimensionally printed subperiosteal implants for maxillectomy reconstruction: report of nine cases

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Abstract. This study was performed to investigate the use of additively manufactured custom-made subperiosteal implants in primary maxillary reconstruction. A retrospective analysis was performed of nine patients who underwent primary reconstruction of the maxilla with these implants between May 2021 and June 2023. The study focused on evaluating the feasibility, effectiveness, and short- to medium-term outcomes, including potential complications. All patients underwent simultaneous implant placement during the same surgery for tumour resection and flap reconstruction and were then monitored for a minimum of 6 months. The first results indicate that these implants are both feasible and effective in achieving stable and functional outcomes, particularly for patients who cannot undergo traditional bone reconstruction. Complication rates were low, with only one case of flap necrosis unrelated to the implant. Additionally, the implants remained stable with no signs of infection or mobility. The main limitations of the study are the small cohort size and short follow-up period. Therefore, these findings must be considered preliminary, and further studies with larger sample sizes and longer-term follow-up are required to confirm the results.

Keywords: Reconstructive surgical procedures; Maxilla; Dental implants; Subperiosteal implantation; Maxillofacial surgery.

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The maxilla plays a critical role in several vital functions such as eating, speaking, and breathing. Therefore, post-resection defects in this area, often resulting from surgeries aimed at treating conditions such as oral cancer, can have severe negative effects on the patient's functionality and quality of life[1]. One of the most significant impacts of maxillary resection defects is on the patient's ability to eat and swallow. The loss of structural integrity in the upper jaw can lead to chewing issues, resulting in dietary restrictions and potentially malnutrition[2,3]. Speech is another major function that can be affected. The maxilla forms part of the vocal tract and plays a significant role

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in articulating sounds. Consequently, post-resection defects can cause speech impairments, making communication more difficult[4,5]. Additionally, the maxilla serves as support for the nose and the middle third of the face. Post-resection defects can thus lead to changes in facial structure and appearance, possibly resulting in negative psychological effects such as lower self-esteem and diminished quality of life[6]. Finally, maxillary tumour resections often necessitate the extraction of dental elements or the removal of both soft tissues and portions of the bone. The alveolar bone loss can make subsequent dental rehabilitation extremely complex or even impossible. This may have additional negative effects on a patient's quality of life leading to further difficulties in eating and speaking[7,8].

Due to the complexities and challenges associated with maxillary reconstruction, microvascular bone flaps such as fibula[9], scapula[10], and iliac crest[11] currently represent the gold standard. These techniques address the three key objectives: providing support to the midfacial soft tissues, ensuring a stable separation between the oral cavity and nasal airway/residual maxillary sinus, and offering sufficient bone volume for dental implant placement[12]. Technological advancements have brought about several improvements to these reconstructive procedures, further enhancing their efficacy. Among these advancements, computer-assisted planning for custom-made reconstruction has been transformative. This technique allows highly accurate surgical planning, tailoring the procedure to the patient's specific anatomical requirements and ensuring the best possible fit for the reconstructed maxilla[13,14]. In addition, the immediate guided placement of endosseous implants can reduce the total number of surgeries and the prosthetic rehabilitation times[15,16].

Recently, some authors have proposed the use of additively manufactured custom-made implants for secondary reconstruction of the maxilla[17–22]. This solution has already been used successfully in clinical practice for the rehabilitation of patients with severely atrophic edentulous jaws, where traditional endosseous implants are not feasible[23–25]. These implants are uniquely advantageous in that they incorporate both the fixation plates for the bone reconstructive flap and the implant abutments for prosthetic support in a single device. The abutments are also positioned under prosthodontic guidance, facilitating dental rehabilitation. The use of metal additive manufacturing, or metal three-dimensional (3D) printing, allows for these implants to be tailored specifically to the patient's anatomy, providing a personalized fit that could potentially improve implant stability and cosmetic outcomes[19].

The application of additively manufactured custom-made implants in primary reconstructions, however, remains a largely unexplored field. At the time of this study, only two case reports addressing this topic could be found in the literature[18,26]. The purpose of this study was to perform a retrospective analysis of a series of patients who had undergone primary reconstruction of the maxilla with additively manufactured implants, and to report potential complications and short- to medium-term outcomes.

Materials and methods

This retrospective study included patients with post-resection maxillary defects who underwent primary reconstruction using either free or pedicled flaps, combined with additively manufactured implants. The patients underwent surgery between May 2021 and June 2023, with evaluations conducted after a minimum follow-up period of 6 months. Patients were excluded from the study in the case of severe general complications in the postoperative period. Surgery was conducted in the Maxillofacial Surgery Unit of the University Hospital of Sassari, Italy, while the clinical records were independently reviewed by a researcher in the Department of Prosthodontics and Gerostomatology of Poznan University of Medical Sciences, Poland.

The study is reported in accordance with the STROBE guidelines for observational studies[27]. Ethical approval was obtained from the Institutional Ethics Committee of Sassari University Hospital.

Oncological planning

All study patients underwent routine preoperative staging, which included an incisional biopsy of the tumour lesion, computed tomography (CT) scans with contrast of the head and neck region, and a total body CT with contrast, as well as magnetic resonance imaging (MRI) with contrast, if deemed necessary, to assess the local extent of the disease, and regional and distant metastasis. Candidates for free fibula flap reconstruction were subjected to lower limb CT angiography to evaluate the patency of the tibio-peroneal vascular axes. Surgical resection planning was approved by the institutional tumour board, based on the clinical and radiological staging. Postoperatively, based on the preoperative staging and the outcome of the definitive histological examination of the surgical specimen, multidisciplinary team assessment of the appropriateness of adjuvant radiochemotherapy treatment was made, and patients were referred if this was deemed indicated.

Implant planning and production

During the planning process, detailed CT scans were acquired for patient staging, as well as digital scans of the dental arches and diagnostic wax-up models. The DICOM (Digital Imaging and Communications in Medicine) and STL (stereolithography) files obtained were forwarded to Sintac Biomedical Engineering (GPI group, Trento, Italy) for creation of the implant. The DICOM files were converted into an STL model using Mimics software (Materialise, Leuven, Belgium). During this process, the quality of the DICOM images was verified to eliminate any artefacts that could potentially compromise the accuracy of the 3D model. The implant design was done using Geomagic Freeform software version 2024.1.0 (3D Systems Inc., Rock Hill, SC, USA). Following the development of the 3D model, a consultation with the surgical team was arranged to determine the extent of bone removal, as well as the design and positioning of the implant, prosthetic connections, and osteosynthesis screw locations (Fig. 1).

For the patients selected for free bone flap reconstruction, the planning of the fibula or iliac crest osteotomies was guided by the CT angiography scans of the lower limbs or the iliac artery system. The quantity, size, and alignment of the segments were tailored to fit the post-resection defect needing repair (Fig. 1). In these instances, the design of the implant incorporated a specific shape and included holes for screws to secure and position the flap properly. An engineer designed the

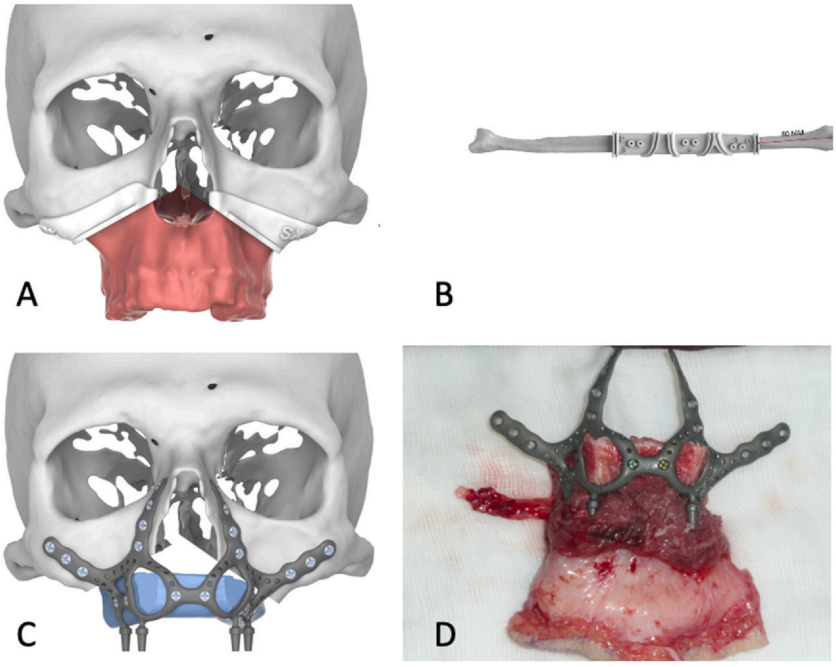

Fig. 1. Case 7 (male, 68 years). (A) Virtual planning of the maxillectomy. (B) Virtual planning of the fibula osteotomies. (C) Virtual planning of the additively manufactured implant. (D) Fibula flap fixed with the additively manufactured implant.

implant, bone resection templates, and potentially the fibula or iliac crest cutting guide. This comprehensive planning document was then submitted to the surgical team for approval.

The implant fabrication utilized direct metal laser sintering technology with a Ti6Al4V titanium superalloy. Additional components, such as cutting guides and anatomical models of the jaw, were created using selective 3D printing technology from polyether ether ketone. After the sintering process, the titanium implant and components were heat-treated to enhance their fracture toughness, ductility at ambient temperatures, dimensional and thermal stability, and resistance to deformation under load. The final steps involved removing the supports, sandblasting the titanium parts, and sterilizing the implant. The entire production cycle took 9 days.

According to EU Regulation 2017/745 (Medical Devices Regulation, MDR) and Italian regulations on medical devices, custom-made implants such as those used in this study are individually designed and manufactured to match specific anatomical and clinical needs for each patient. These devices do not require standard CE marking or regulatory approval for commercial distribution. However, the production of custom-made implants must comply strictly with MDR requirements, including detailed prescriptions, design documentation, biocompatibility certificates, appropriate sterilization protocols, and full material traceability, under the direct responsibility of the prescribing physician.

Surgery

All surgical procedures were performed under general anaesthesia according to the oncological plan established by the institutional tumour board. The patients underwent maxillectomy, including resection of the neoplasm, utilizing bone resection guides designed from the preoperative planning. Intraoperatively, frozen section analysis was conducted on the resection margins to achieve clear margins. An ipsilateral or bilateral neck dissection was performed based on the preoperative staging, in accordance with the guidelines[28]. Harvesting of the reconstructive flaps was performed using techniques described previously[11,29–31]. In cases involving bone reconstruction, the additively manufactured implant served as the osteosynthesis plate for securing the bone segments. The implants were fixed to the bone using 2.0 mm titanium osteosynthesis screws (Stryker Corp., Kalamazoo, MI, USA) (Fig. 2). In instances where screw retention was insufficient, 2.3 mm rescue screws were employed to ensure

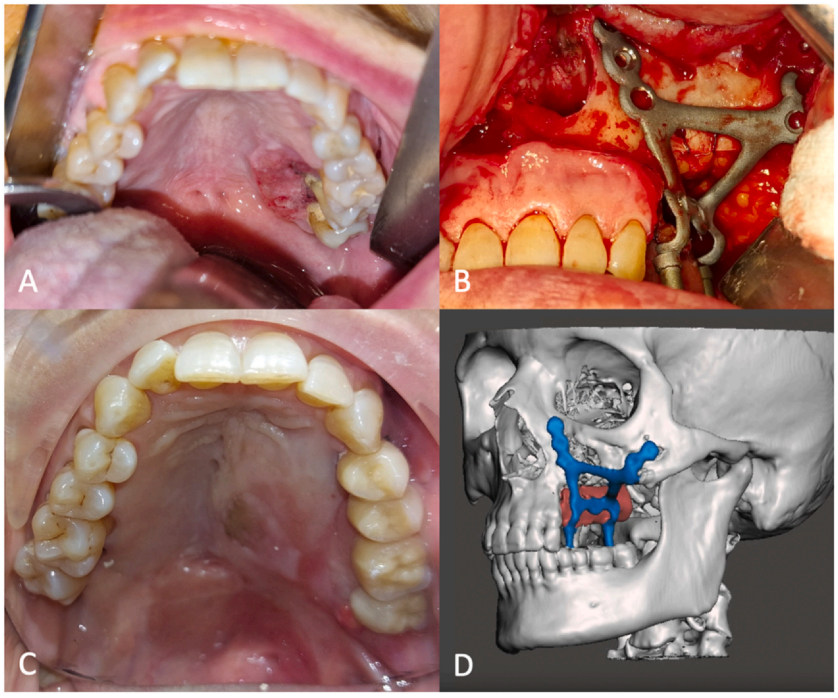

Fig. 2. Case 3 (female, 76 years). (A) Preoperative view showing squamous cell carcinoma of the left maxilla. (B) Reconstruction with an additively manufactured implant and fibula osteomyocutaneous flap. (C) Intraoral view 17 months after surgery. (D) Follow-up 3D CT scan at 12 months.

adequate fixation torque. Postoperatively, the patients were monitored on the maxillofacial surgery ward and discharged as soon as their condition allowed. The provisional prosthesis was delivered upon tissue healing, approximately 30 days postdischarge. The final prosthesis was delivered 6 months after surgery.

Evaluation protocol

Following surgery, each patient underwent thorough clinical and radiological follow-up to monitor potential complications. The soft tissue health surrounding the abutments was evaluated 6 months postoperatively, at the time of final prosthesis placement, with subsequent assessments conducted at 2-month intervals thereafter. Implant exposure was assessed using a five-point scale: score 0 for no exposure, score 1 for exposure of the vertical arm of the abutment, score 2 for exposure of the horizontal arm of the implant, score 3 for exposure of the horizontal arm and at least one osteosynthesis screw, and score 4 for exposure with associated mobility. Each exposure level was further categorized into subgroups A and B based on the presence or absence of symptoms of pain or inflammation[32,33]. CT scans were performed at the end of the treatment process and then every 6 months.

Results

The study included nine patients who underwent primary reconstructive surgery with additively manufactured custom-made implants following the resection of maxillary tumours, between May 2021 and June 2023 (Table 1; Supplementary material Table S1). The cohort comprised seven male and two female patients, ranging in age from 45 to 90 years (mean 70.8 years). The tumour type was squamous cell carcinoma (SCC) in five patients, high-grade osteosarcoma in two patients, high-grade chondrosarcoma in one patient, and low-grade osteosarcoma in one patient.

The maxillectomies performed were classified according to the Brown classification system[34]. Four cases were classified as 2D, three as 2B, one as 2C, and one as 4D. The surgical approach to the neoplasm was a transfacial Weber–Ferguson approach in one case. The remaining eight cases were approached intraorally with facial degloving, with one of these cases additionally requiring an access mandibulotomy.

The reconstructive approaches varied based on the tumour type, location of the resection, and patient comorbidities. The most frequently used technique was the fibula free flap, employed in four cases. Other techniques included the Bichat fat pad flap, temporalis muscle flap, scapula free flap, iliac crest bone graft combined with bilateral buccinator myomucosal flaps, and latissimus dorsi flap. The reconstructive flaps remained vital in all cases except one. In this case, necrosis of a fibula free flap occurred due to venous stasis caused by thrombosis of the efferent vein. The patient subsequently underwent a second surgery where the fibula flap was removed, and the surgical defect was closed with a temporalis muscle flap. Subsequently, the temporalis flap also suffered partial necrosis, leading to the formation of an oronasal fistula, which was later closed using a buccinator myomucosal flap based superiorly, on the angular artery of the nose. Another patient with multiple comorbidities, for whom a free flap reconstruction was not feasible, underwent reconstruction of the entire maxilla using a temporalis muscle flap. This case was complicated by surgical wound dehiscence, resulting in a small oroantral fistula along the distal margin of the flap, which was subsequently closed with a palatal obturator extension, incorporated into the prosthesis loaded on the additively manufactured implant (Fig. 3).

The duration of follow-up ranged from 6 to 20 months (mean 13.7 months). One patient died 20 months post-surgery due to unrelated general health conditions. Five patients received postoperative radiotherapy, of whom four received combined chemoradiotherapy. In one of these cases, severe mucositis developed due to the cumulative radiation dose at the level of the transmucosal abutments. This complication necessitated a temporary suspension of the radiotherapy, although the treatment was eventually completed successfully.

All implants were successfully positioned and loaded without any signs of infection or mobility. No prosthetic complications were reported. Radiological assessments conducted at 6 months and at 1 year post-surgery revealed no complications related to the osteosynthesis materials; no loose

Table 1. Summary of patient characteristics and clinical data.

	Number of patients
Sex	
Male	7 (77.8%)
Female	2 (22.2%)
Intersex	0 (0%)
Age (years), mean ± SD	70.8 ± 14.9
Smoking status	
Current	4 (44.5%)
Former	3 (33.3%)
Never	2 (22.2%)
Tumour histology	
Squamous cell carcinoma	5 (55.6%)
Osteosarcoma	3 (33.3%)
Chondrosarcoma	1 (11.1%)
Maxillectomy classification (Brown)	
2B	3 (33.3%)
2C	1 (11.1%)
2D	4 (44.4%)
4D	1 (11.1%)
Reconstructive flap	
Fibula free flap	4 (44.4%)
Scapula free flap	1 (11.1%)
Iliac bone graft + buccinator myomucosal flap	1 (11.1%)
Bichat fat pad flap	1 (11.1%)
Temporalis muscle flap	1 (11.1%)
Latissimus dorsi flap	1 (11.1%)
Adjuvant treatment	
Radiotherapy	1 (11.1%)
Chemoradiotherapy	4 (44.4%)
None	4 (44.4%)

SD, standard deviation.

Fig. 3. Case 1 (male, 90 years). (A) Residual oroantral fistula after total maxillectomy and reconstruction with a temporalis muscle flap and additively manufactured implant. (B) Closure of the fistula with a palatal obturator extending to the dental prosthesis.

screws or signs of bone resorption around the implants were detected.

Regarding the health status of the soft tissues, eight implants showed no signs of recession, while one implant exhibited vertical arm exposure above one of the abutments without signs of infection in the surrounding tissues (score 1A).

Discussion

There is increasing evidence that additively manufactured subperiosteal implants are a reliable solution for the rehabilitation of an atrophic jaw[32,33,35–40]. The use of these custom-made implants for primary maxillary reconstruction, as presented in this study, shifts the focus from traditionally explored secondary reconstructions to the potential of primary reconstruction using this technology. This study is novel in reporting a small series of patients who had undergone primary maxillary reconstruction with additively manufactured implants, providing insights into the potential benefits and challenges of this approach.

The prompt availability of patient-specific implants is crucial in oncological surgery. In the patient cases presented here, the implants were available approximately 10 days after the initial diagnostic CT scan. This timeframe, which does not delay the surgery, is the result of a faster manufacturing and shipping process compared to the past. It enables the use of patient-specific implants even in primary cases. Previous studies have focused primarily on secondary reconstruction, where the anatomical landscape has already been altered by prior surgeries, making it a different scenario compared to primary reconstruction. Korn et al.[19] discussed the challenges of dental rehabilitation in patients with extended maxillary defects following ablative surgery. They introduced the concept of patient-specific implants as a promising alternative for these complex reconstructions, emphasizing the benefits of avoiding time-consuming and invasive augmentation procedures. Their study highlights the potential of patient-specific implants in providing stable and predictable results for patients who have undergone extensive tumour resections, where conventional implants might not be feasible. However, their study was limited to secondary reconstructions.

The current study demonstrates the feasibility of using additively manufactured implants for primary reconstruction in cases where the anatomical structures have been altered recently by tumour resection and have not yet undergone shrinkage due to postoperative scarring. The immediate positioning of these implants allows simultaneous reconstruction of the bone and soft tissues, addressing the unique challenges of maintaining structural integrity, providing support for facial aesthetics, and facilitating early prosthetic rehabilitation.

An important theoretical advantage of additively manufactured implants is their potential utility in patients who are not suitable candidates for traditional bone reconstruction or, hypothetically, in those cases in which a traditional reconstruction fails. These implants provide critical support for prostheses in patients who would otherwise be very difficult to rehabilitate (Fig. 4). For individuals with severe bone deficiencies or where conventional bone grafting techniques are not suitable, these implants offer a personalized solution that can restore function and aesthetics. Furthermore, additively manufactured implants can also provide a solid anchorage for obturator prostheses in patients with residual oronasal or oroantral communications. By offering a stable and secure foundation, they eliminate the need for bulky and often unstable obturator prostheses, which can be uncomfortable and difficult for patients to manage.

In primary rehabilitations, where the defect is not yet present but can only be estimated from preoperative CT scans, meticulous preoperative planning of the

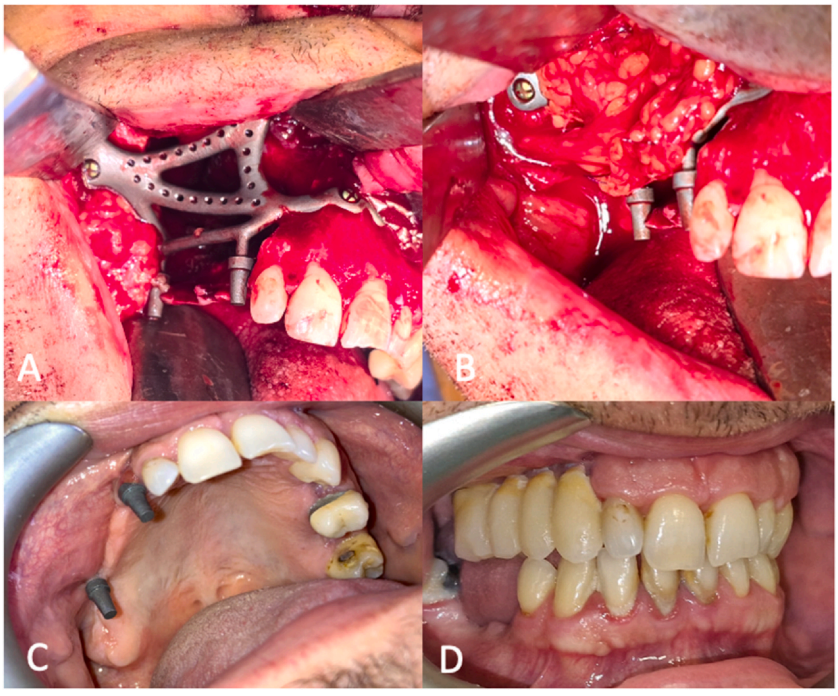

Fig. 4. Case 9 (male, 45 years). (A) Subperiosteal implant fixed in situ after maxillectomy for low-grade osteosarcoma. (B) Bichat fat pad flap transposed to cover the implant. (C) Intraoral view 6 months after surgery. (D) Prosthesis in place.

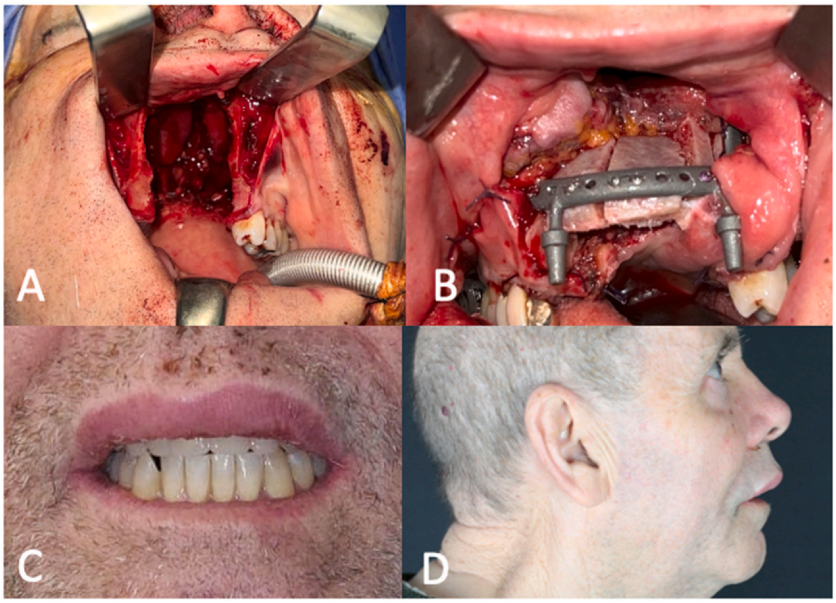

Fig. 5. Case 6 (male, 86 years). (A) Post-resection defect after removal of a high-grade chondrosarcoma of the premaxilla. (B) Reconstruction with an additively manufactured implant and iliac crest grafts. The grafts were covered with buccinator myomucosal flaps. (C) Dental prosthesis in place 12 months after surgery. (D) Profile of the patient 12 months after the operation, which shows excellent projection of the upper jaw.

resection is crucial. During this planning phase, it is essential to anticipate the possibility of a more extensive resection than initially planned. Therefore, the implant design should include supplemental holes and sufficiently long arms to ensure secure fixation even if the resection is broader than expected preoperatively. This foresight in planning is essential to maintain the adaptability and success of the implant during surgery, ensuring that any intraoperative modifications do not compromise the stability or functionality of the implant.

One of the potential issues associated with additively manufactured implants, particularly in patients undergoing radiotherapy, is the accumulation of toxicity around the transmucosal abutments. Radiotherapy can cause significant complications, such as mucositis and delayed healing, especially when the abutments remain exposed during treatment. This problem can be mitigated by using screw abutments instead of monolithic cementable abutments. Screw abutments have the advantage of being submerged below the mucosa during radiotherapy and can be uncovered only after the completion of the radiotherapy treatment.

The study results show that the primary application of these implants is not only feasible but also effective in achieving stable and functional outcomes (Fig. 5). All implants in this series were successfully positioned and remained stable throughout the follow-up period, with no signs of infection or mobility. This is consistent with the findings of Korn et al.[19] for secondary reconstructions.

The complication rate in the present study was low, with only one case of flap necrosis, which was unrelated to the implant. This compares favourably with the complication rates reported in other studies involving complex maxillary reconstructions[41,42]. Importantly, the complications observed in this study, such as implant exposure and mucositis, were manageable and did not lead to implant failure, reinforcing the potential of these implants in challenging reconstructive scenarios.

This study has significant limitations that should be acknowledged. The small cohort size of only nine patients substantially limits the generalizability and robustness of the findings. Furthermore, the short follow-up period, ranging from 6 to 20 months, does not allow conclusions to be drawn regarding the long-term effectiveness, stability, and safety of the implants. Future research, ideally with larger patient cohorts and longer-term follow-up, is essential to confirm these preliminary results and more comprehensively evaluate long-term outcomes and potential complications. Further prospective studies with standardized protocols are needed to confirm the results and explore the full spectrum of potential complications and outcomes.

Ethical approval

Approved by the Institutional Ethics Committee of Sassari University Hospital (approval number 22/2025).

Patient consent

Obtained.

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Competing interests

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijom.2025.07.001.

References

1. Murphy J, Isaiah A, Wolf JS, Lubek JE. Quality of life factors and survival after total or extended maxillectomy for sinonasal malignancies. *J Oral Maxillofac Surg* 2015;**73**:759–63.
2. Yanagi A, Murase M, Sumita YI, Taniguchi H. Investigation of nutritional status using the mini nutritional assessment-short form and analysis of the relevant factors in patients with head and neck tumor. *Gerodontology* 2017;**34**:227–31.
3. Kamiyanagi A, Sumita Y, Ino S, Chikai M, Nakane A, Tohara H, Minakuchi S, Seki Y, Endo H, Taniguchi H. Evaluation of swallowing ability using swallowing sounds in maxillectomy patients. *J Oral Rehabil* 2018;**45**:126–31.
4. Michi K. Functional evaluation of cancer surgery in oral and maxillofacial region: speech function. *Int J Clin Oncol* 2003;**8**:1–17.
5. Seignemartin CP, Miranda ME, Luz JG, Teixeira RG. Understandability of speech predicts quality of life among maxillectomy patients restored with obturator prosthesis. *J Oral Maxillofac Surg* 2015;**73**:2040–8.
6. Riefer JM, Tang JA, Wolfaardt J, Harris J, Seikaly H. Comparison of speech and

aesthetic outcomes in patients with maxillary reconstruction versus maxillary obturators after maxillectomy. *J Otolaryngol Head Neck Surg* 2011;**40**:40–7.
7. Tang JA, Rieger JM, Wolfaardt JF. A review of functional outcomes related to prosthetic treatment after maxillary and mandibular reconstruction in patients with head and neck cancer. *Int J Prosthodont* 2008;**21**:337–54.
8. Buurman DJM, Speksnijder CM, de Groot RJ, Kessler P, Rieger JM. Mastication in maxillectomy patients: a comparison between reconstructed maxillae and implant supported obturators: a cross-sectional study. *J Oral Rehabil* 2020;**47**:1171–7.
9. Zhang WB, Wang Y, Liu XJ, Mao C, Guo CB, Yu GY, Peng X. Reconstruction of maxillary defects with free fibula flap assisted by computer techniques. *J Craniomaxillofac Surg* 2015;**43**:630–6.
10. Ferri A, Perlangeli G, Bianchi B, Zito F, Sesenna E, Ferrari S. Maxillary reconstruction with scapular tip chimeric free flap. *Microsurgery* 2021;**41**:207–15.
11. Bianchi B, Ferri A, Ferrari S, Copelli C, Boni P, Sesenna E. Iliac crest free flap for maxillary reconstruction. *Microsurgery* 2010;**68**:2706–13.
12. Lee ZH, Cripps C, Rodriguez ED. Current concepts in maxillary reconstruction. *Plast Reconstr Surg* 2022;**150**:168e–75e.
13. Melville JC, Manis CS, Shum JW, Alsuwied D. Single-unit 3D-printed titanium reconstruction plate for maxillary reconstruction: the evolution of surgical reconstruction for maxillary defects—a case report and review of current techniques. *J Oral Maxillofac Surg* 2019;**77**:874.e1–874.e13.
14. Idris S, Logan H, Tabet P, Osswald M, Nayar S, Seikaly H. The accuracy of 3D surgical design and simulation in prefabricated fibula free flaps for jaw reconstruction. *J Pers Med* 2022;**12**:1766.
15. Patel SY, Kim DD, Ghali GE. Maxillofacial reconstruction using vascularized fibula free flaps and endosseous implants. *Oral Maxillofac Surg Clin N Am* 2019;**31**:259–84.
16. Allen Jr RJ, Nelson JA, Polanco TO, Shamsunder MG, Ganly I, Boyle J, Rosen E, Matros E. Short-term outcomes following virtual surgery assisted immediate dental implant placement in free fibula flaps for oncologic mandibular reconstruction. *Plast Reconstr Surg* 2020;**146**:768e–76e.
17. Vosselman N, Marema BJ, Schepman KP, Raghoebar GM. Patient-specific subperiosteal zygoma implant for prosthetic rehabilitation of large maxillary defects after oncological resection. *Int J Oral Maxillofac Surg* 2019;**48**:115–7.
18. Mommaerts MY. Reconstruction of a subtotal maxillectomy defect using a customized titanium implant in a 4-year-old child: an 8-year follow-up report. *Front Surg* 2020;**7**:28.
19. Korn P, Gellrich NC, Jehn P, Spalthoff S, Rahlf B. A new strategy for patient-specific implant-borne dental rehabilitation in patients with extended maxillary defects. *Front Oncol* 2021;**11**:718872.
20. Cebrián Carretero JL, Del Castillo Pardo de Vera JL, Montesdeoca García N, Garrido Martínez P, Pampín Martínez MM, Aragón Niño I, Navarro Cuéllar I, Navarro Cuéllar C. Virtual surgical planning and customized subperiosteal titanium maxillary implant (CSTMI) for three-dimensional reconstruction and dental implants of maxillary defects after oncological resection: case series. *J Clin Med* 2022;**11**:4594.
21. Garrido-Martinez P, Quispe-Lopez N, Montesdeoca-Garcia N, Esparza-Gomez G, Cebrian-Carretero JL. Maxillary reconstruction with subperiosteal implants in a cancer patient: a one-year follow-up. *J Clin Exp Dent* 2022;**14**:e293–7.
22. Kondaka S, Dal Singh V, Vadlamudi C, Rao Bathala L. Prosthetic rehabilitation of untailored defects using patient-specific implants. *Dent Res J* 2022;**19**:83.
23. Vaira LA, Biglio A, Salzano G, Pispero A, Lechien JR, De Riu G. Custom fabricated subperiosteal implants for sectional rehabilitation of severely atrophic maxillae: a technical note. *J Oral Maxillofac Surg* 2025;**86**:728–37.
24. Roy M, Cerea M, Hedzelek W, Vaira LA, Dorocka-Bobkowska B. Additively manufactured subperiosteal implants for the rehabilitations of lateral incisors agenesis—a case series. *J Stomatol Oral Maxillofac Surg* 2025 Jan 25. https://doi.org/10.1016/j.jormas.2025.102263
25. Van den Borre C, Otero JJ, Loomans N, Samama M, Lempert J, Baltensperger M, Termont A, Castro R, Mommaerts MY. Retrospective analyses of additively manufactured subperiosteal jaw implants in the mandible. *J Craniomaxillofac Surg* 2025;**53**:905–10.
26. De Riu G, Soma D, Biglio A, Raho MT, Mura D, Michelon F, Salzano G, Piombino P, Lechien JR, Vaira LA. Primary reconstruction of total maxillectomy with custom-made subperiosteal implant and temporal muscle flap: a case report. *Appl Sci* 2023;**13**:6269.
27. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. STROBE Initiative. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007;**335**:806–8.
28. National Comprehensive Cancer Network. NCCN clinical practice guidelines in oncology: head and neck cancers, version 1. 2024. NCCN.org; 2023. ⟨https://www.nccn.org/professionals/physician_gls/pdf/head-and-neck.pdf⟩ [Accessibility verified 27 August 2024].
29. Peng X, Mao C, Yu GY, Guo CB, Huang MX, Zhang Y. Maxillary reconstruction with the free fibula flap. *Plast Reconstr Surg* 2005;**115**:1562–9.
30. Massarelli O, Vaira LA, Biglio A, Gobbi R, Piombino P, De Riu G. Rational and simplified nomenclature for buccinator myomucosal flaps. *Oral Maxillofac Surg* 2017;**21**:453–9.
31. Massarelli O, Vaira LA, Gobbi R, Biglio A, Dell'aversana Orabona G, De Riu G. Soft palate functional reconstruction with buccinator myomucosal island flaps. *Int J Oral Maxillofac Surg* 2018;**47**:316–23.
32. Vaira LA, Biglio A, Roy M, Salzano G, Troise S, Abbate V, Mayo-Yanez M, Lechien JR, Piombino P, De Riu G. Full-arch rehabilitation of severely atrophic maxilla with additively manufactured custom-made subperiosteal implants: a multicenter retrospective study. *J Craniomaxillofac Surg* 2024;**52**:991–8.
33. Vaira LA, Biglio A, Favro A, Salzano G, Abbate V, Lechien JR, De Riu G. Implant-prosthetic rehabilitation of the atrophic posterior mandible with additively manufactured custom-made subperiosteal implants: a cohort study. *Int J Oral Maxillofac Surg* 2024;**53**:533–40.
34. Brown JS, Shaw RJ. Reconstruction of the maxilla and midface: introducing a new classification. *Lancet Oncol* 2010;**11**:1001–8.
35. Mommaerts MY. Additively manufactured sub-periosteal jaw implants. *Int J Oral Maxillofac Surg* 2017;**46**:938–40.
36. Mommaerts MY. Evolutionary steps in the design and biofunctionalization of the additively manufactured sub-periosteal jaw implant 'AMSJI' for the maxilla. *Int J Oral Maxillofac Surg* 2019;**48**:108–14.
37. De Moor E, Huys SEF, van Lenthe GH, Mommaerts MY, Vander Sloten J. Mechanical evaluation of a patient-specific additively manufactured subperiosteal jaw implant (AMSJI) using finite-element analysis. *Int J Oral Maxillofac Surg* 2022;**51**:405–11.
38. Van den Borre C, Rinaldi M, De Neef B, Loomans NAJ, Nout E, Van Doorne L, Naert I, Politis C, Schouten H, Klomp G, Beckers L, Freilich MM, Mommaerts MY. Patient- and clinician-reported outcomes for the additively manufactured sub-periosteal jaw implant (AMSJI) in the maxilla: a prospective multicentre one-year follow-up study. *Int J Oral Maxillofac Surg* 2022;**51**:243–50.
39. Van den Borre C, De Neef B, Loomans NAJ, Rinaldi M, Nout E, Bouvry P, Naert I, Mommaerts MY. Patient satisfaction and impact on oral health after

maxillary rehabilitation using a personalized additively manufactured subperiosteal jaw implant (AMSJI). *J Pers Med* 2023;**13**:297.

40. Vaira LA, Biglio A, Salzano G, Lechien JR, De Riu G. Additively manufactured custom-made subperiosteal implant rehabilitation for severely atrophic maxillary molar area: a technical note. *J Stomatol Oral Maxillofac Surg* 2024; **125**(5S1):101917.
41. Mücke T, Hölzle F, Loeffelbein DJ, Ljubic A, Kesting M, Wolff KD, Mitchell DA. Maxillary reconstruction using microvascular free flaps. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**111**: 51–7.
42. Yu S, Zhang WB, Wang Y, Mao C, Guo CB, Peng X. Reconstruction of complete bilateral maxillary defects with free flaps. *J Craniofac Surg* 2022; **33**:e550–2.

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