Customised, digitally manufactured subperiosteal implant for the treatment of a completely edentulous atrophic maxilla

A case report on a new minimally invasive SP4 implant design

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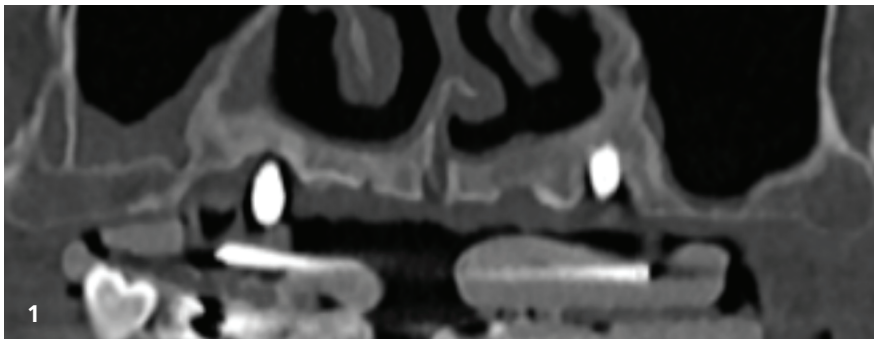
The rehabilitation of atrophic jaws with implant-supported fixed restorations and immediate loading is still a challenge today. The aim of this clinical case is to present an innovative protocol for the treatment of advanced atrophic jaws with a new generation of subperiosteal implants manufactured using modern digital technology.

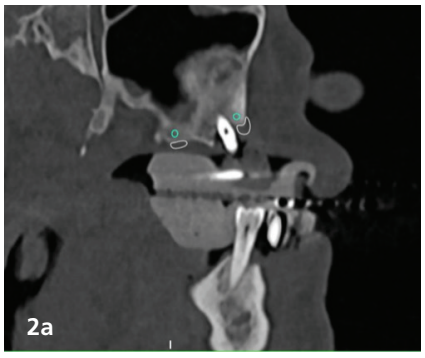
A case of extreme bone atrophy in the maxilla due to failure of the osseointegrated implant was treated. This article focuses on illustrating the use of a new minimally invasive subperiosteal implant design (3Dfast). All phases of the protocol from CBCT scan to immediate loading are described in detail. This case supports the use of fully customised subperiosteal implants as a minimally invasive and reliable alternative for the dental rehabilitation of atrophic, completely edentulous cases. Despite this single case demonstrating the efficacy of the protocol, further long-term studies with large numbers of patients are needed to confirm the findings so far.

Introduction

The restoration of atrophic jaws with implant-supported fixed dentures still represents a clinical challenge today. Many techniques have been described in the literature to solve this problem. Reconstructive procedures such as autogenous bone grafting or guided bone regeneration[1] are frequently used. However, autogenous bone grafting requires a second surgical procedure,[2] which involves additional morbidity,[3] and immediate loading is not always recommended,[4] plus the patient must wear a removable denture for a long period of time, e.g. more than one year.

However, we must consider that the surgical procedure requires general anaesthesia and hospitalisation. Guided bone regeneration, especially the vertical one, is often only possible to a limited extent and is also associated with possible complications in completely atrophied jaws.[5] Both techniques require several months for the graft to heal.[6] Alternative techniques for the rehabilitation of atrophic jaws, such as tilted implants[7] and zygo-





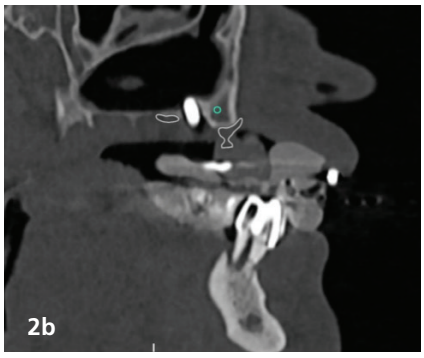


Fig. 1: Panoramic X-ray derived from a 3D scan shows class 5/6 Misch classification of bone atrophy.
Fig. 2: CBCT shows two existing osseointegrated implants that have failed due to advanced peri-implantitis.

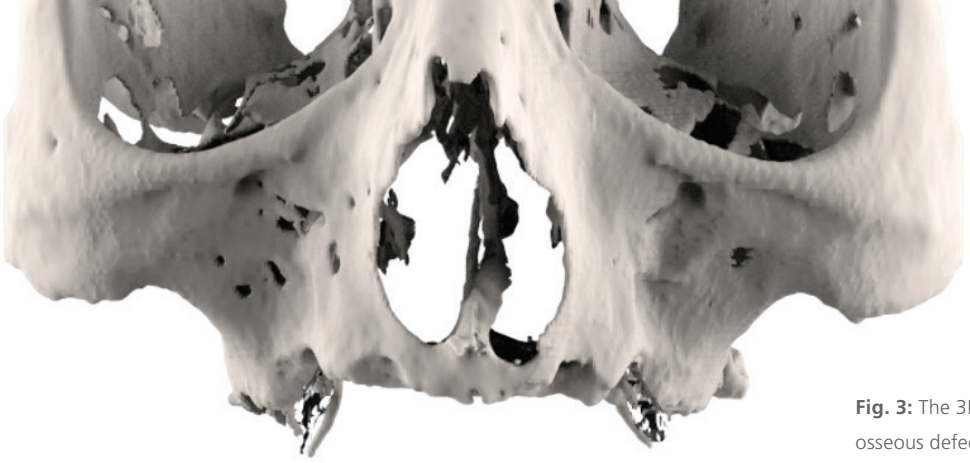


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Fig. 3: The 3D rendering shows two deep intraosseous defects around the existing implants.

matic implants,[8] seem to provide stable long-term results. Atrophic jaws have anatomical changes that increase the risk of injury to important structures, so that special surgical skills are required during surgery.

Zygomatic implants can often be performed under general anaesthesia, depending on the surgeon's experience and the patient's condition. A favourable zygoma bone is essential to support the implant.[8] In addition, complications such as late lateral exposure and peri-implantitis are difficult to manage during healing and the unavoidable removal of the implant is a distressing solution. In a severely atrophied jaw, the use of short implants is still controversial.[9]

Other techniques such as the sinus lift,[10] the lateralisation of the inferior alveolar nerve[11] or the osteogenic distraction[12] have shown varying results in the literature. Customised subperiosteal implants suitable for both maxillary atrophy and mandibular bone deficits[13–15] are again being considered as a solution for the rehabilitation of atrophic jaws, and several protocols have been developed for subperiosteal implant techniques.

Case report

In March 2021, a 67-year-old patient with advanced bone loss of the maxilla was referred to our department for surgical treatment with final implant-supported fixed rehabilitation. The evaluation of the diagnostic CBCT (3D accuitomo 170, Morita) showed an advanced atrophy both in the premaxilla and in the area of the maxillary sinus. Furthermore, two conventional osseointegrated implants with advanced peri-implantitis were already in place and were to be removed during the implant surgery (Figs. 1 & 2).[18]

The image confirmed the advanced bone resorption and the deeper bone defects around the existing osseointegrated implants (Fig. 3). The main exclusion criteria (heavy smoker, recent cancer treatment and bruxism) were considered to admit the patient for the surgical procedure.

Conventional surgical treatments such as bone grafting and zygomatic implants have been clearly explained in terms of the risk of failure and complications. Graft resorption, delayed lack of osseointegration and stability achieved, morbidity and duration of treatment including the need to wear a temporary conventional removable prosthesis for a long period of time prior to implantation were explained to the patient.

Regarding the zygomatic approach, all surgical aspects, including the necessary skills of the surgeon to avoid surgical risks, the delayed complications such as sinusitis with infection and/or implant loosening and peri-implantitis[17,18] were clearly explained. Finally, a detailed discussion was dedicated to the customised subperiosteal implant option.[20] The 3D visualisation and a prototype of the implant were very useful to correctly describe the surgical procedure to the patient and are always necessary to make the final decision.

The detailed follow-up of the conventional options in comparison with the customised digitally fabricated implants has been discussed.[21] A minimally invasive procedure combined with immediate loading can be a big advantage of this innovative approach, which is why the patient considered a subperiosteal implant to be the preferred option and signed a special informed consent form for the treatment.

Materials and methods

After a conventional wax-up, a radiographic scan prosthesis was delivered for a preoperative CBCT. During the scan, the patient was wearing a relined original appliance in occlusion labelled "3D bite" within the markings for the digital alignment of the images obtained from the radiographs (Fig. 4). The reference points also help in the alignment between the 3D rendered volume of the anatomy and the model obtained from the scanning (lab-based or intra-oral) of the upper and lower dentition and the 3D bite.

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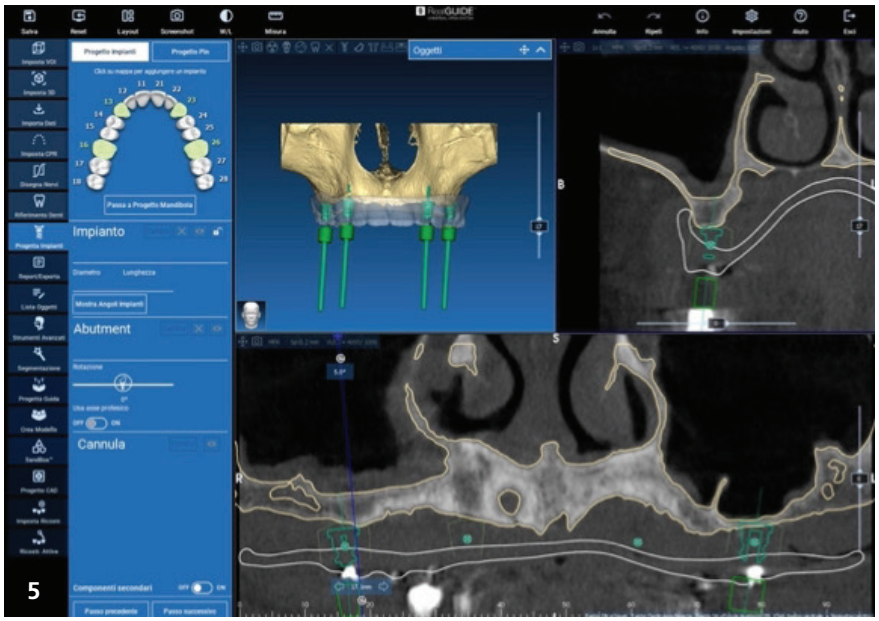
Fig. 4: The original bite, called the "3D bite", within the radiopaque markers is used during the CBCT acquisition to obtain the alignment between the rendering from the CBCT and the STL from the models.



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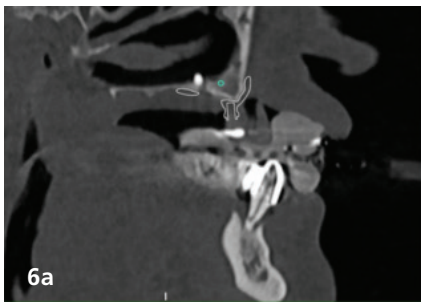

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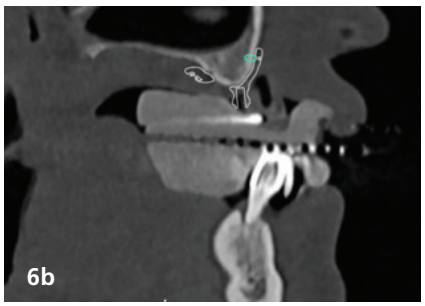

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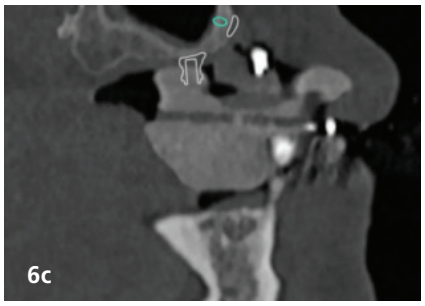

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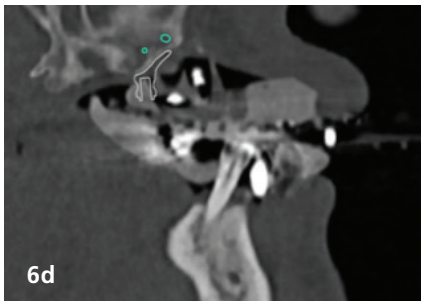

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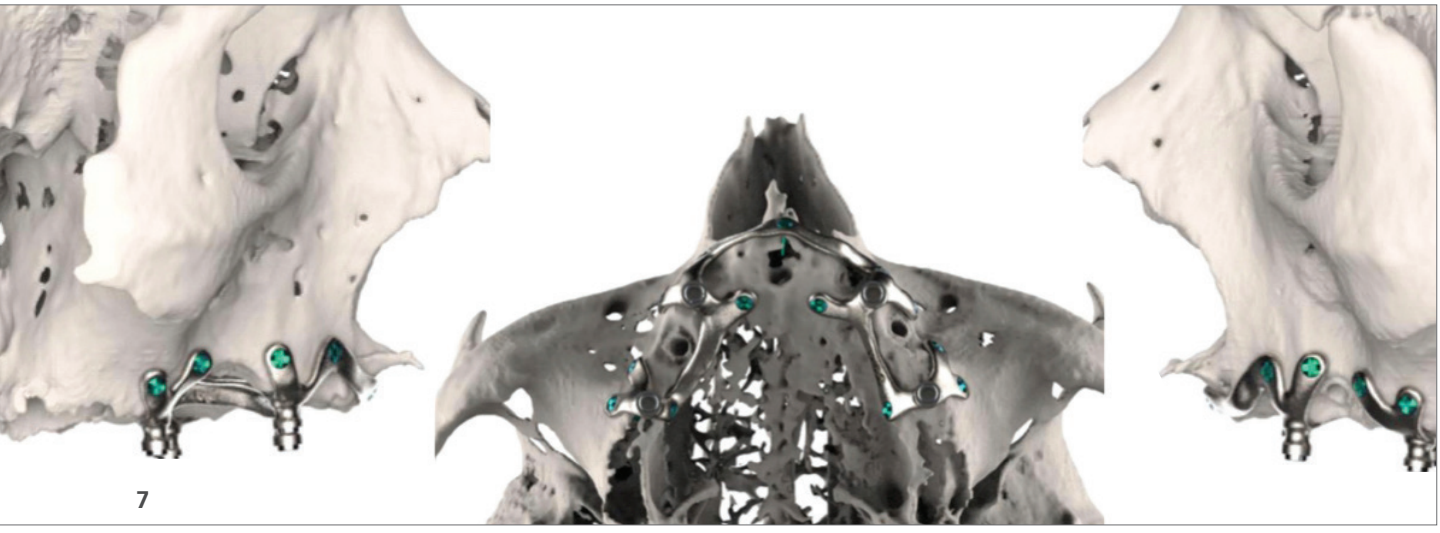
Using the Real Guide platform (3DIEMME Bioimaging Technologies), the clinician can interactively place the abutment from an existing library. According to our protocol and as suggested and previously published by Dr Linkow, the prosthetic position corresponds bilaterally to the first molar and the canine, which is why we named the implant "SP4" (Figs. 5 & 6). The plan was then sent to the 3Dfast company (3Dfast) to be uploaded with specialised software (Freeform, Artec 3D) and the implant has been designed.

All details are controlled by a haptic device. Therefore, our protocol works in a completely digital environment. The prepositioned abutment, which corresponds to the anatomical abutment of the maxilla, is the main reference for the design of the implant. The positioning of the screws is the first step before the contours of the primary and secondary strips are defined (Fig. 7).

All screws are planned in length and direction according to anatomy such as the sinus and nasal cavity, the mental nerve and adjacent teeth (Fig. 8). The positioning of the screw according to the nasal spine,

Fig. 5: Using the real guide platform from the existing library, the prosthetic connections are placed in the design. **Fig. 6:** The four connectors must be placed according to the anatomical pillar of the maxilla: canine and first molar bilaterally. **Fig. 7:** The positioning of the screws is the first step to start the implant design.



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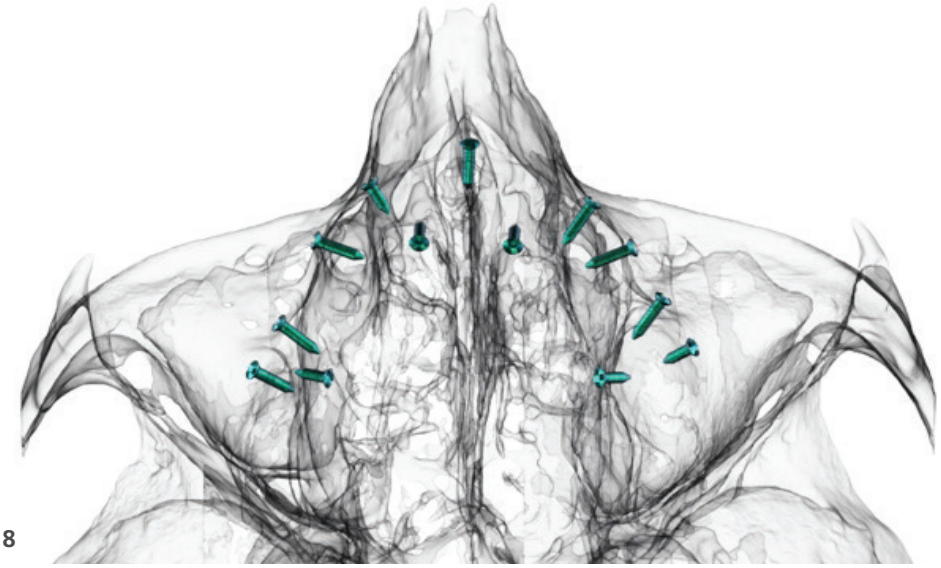
which is another pillar of the maxillary anatomy, is key to predicting the stability of the implant after loading over time. This is another important detail that has been described and published by Dr Linkow for several years. The final file with all the details is then sent digitally to the laser sintering machine (Sint & Mill, Spring Engineering).

The subperiosteal implant is then sent to post-production management and finishing (TRUMPF). The platforms are microscopically machined, and the surface is chemically and mechanically treated to obtain a smooth texture on the outside and limited roughness on the inside of the implant body.

Ten to fifteen days are sufficient for delivery of a package containing:

- a "3D flap" to guide the incision
- a replica of the anatomy
- a prototype of the implant
- a subperiosteal implant
- a "3D bridge stabiliser" to facilitate the placement of the implant and correctly perform an efficient immediate loading
- the temporary bridge digitally made of PMMA (Fig. 9)



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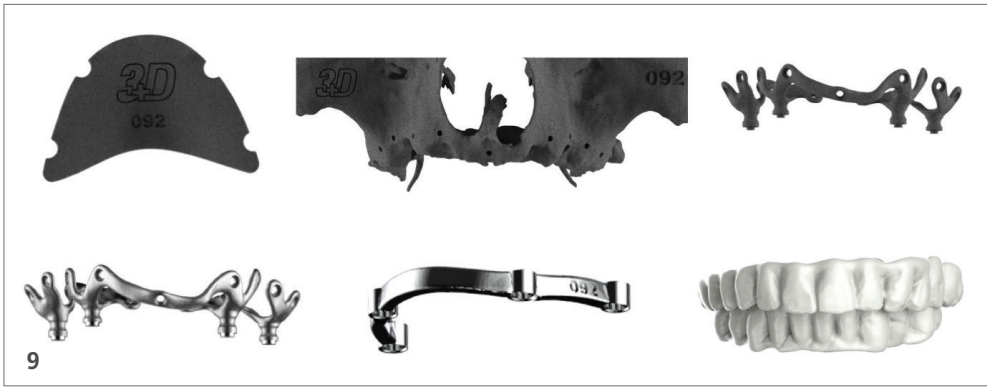

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Fig. 8: All screws are digitally placed according to the anatomy to avoid the risk of damaging adjacent structures. **Fig. 9:** The package contains six different devices: the 3D flap for the incision, the replica and prototype of the implant for conservative bone exposure, the stabiliser 3D bridge for implant placement and immediate loading, and the provisional to simplify and shorten the loading protocol.

All surgical devices are autoclavable because they are made digitally from layers of polyamide (HD Printer). The company produces the bar structure using a laser sintering process with a chromium/cobalt alloy to ensure the accuracy of the passive fit between the implant platform and the temporary bridge.

The clinician can choose to receive only the STL file from the company to send to the trusted dental technician to fabricate the temporary bridge using the in-lab prosthetic digital process.

Six months later, in case of infection or mobility, the clinician can finalise the case using conventional prosthetic procedures. Finally, we would like to point out that the implant can initially be made with a prosthetic connection for a cemented restoration. Our suggestion is to limit this use, if desired, to partially edentulous rehabilitations.

Surgical protocol

The procedure can be performed without hospitalisation and conventional local anaesthesia is always sufficient for the entire procedure. Intravenous sedation is recommended for anxious patients. Antibiotics (amoxicillin) three times a day for ten days, cortisone (Bentelan) twice a day for three days and chlorhexidine rinses are prescribed. Cortisone injection is also recommended at the time of surgery, both locally and intravenously, to avoid swelling and consequent traction of the stitches. After infiltration with articaine with adrenaline 4% (Pierrel), a complete flap is precisely designed using the "3D Flap" device (Fig. 10). The incision line follows the previously planned position of the emergence of the prosthesis platform, allowing efficient repositioning of the soft tissues during suturing. This approach is important to avoid dangerous vertical incisions. The entire flap is reflected to expose only the portion of bone required for implant placement. The sterilised implant prototype is essential in this part of the procedure to minimise bone exposure and preserve its natural vascularisation (Fig. 11). At this stage, the positioning of the subperiosteal implant, assembled with the "3D bridge" for easy placement, has always been achieved with immediate self-stabilisation (Fig. 12). Keeping the "3D bridge" in place, the "main screws" are positioned.

The sequence must always be: first in the nasal spine, two for each buccal side distally, and then two palatal medially. The 3D bridge can then be removed to facilitate screw placement; finally, screw stabilisation is completed using a special screwdriver. In case of loosening, an additional self-tapping pre-prepared screw,

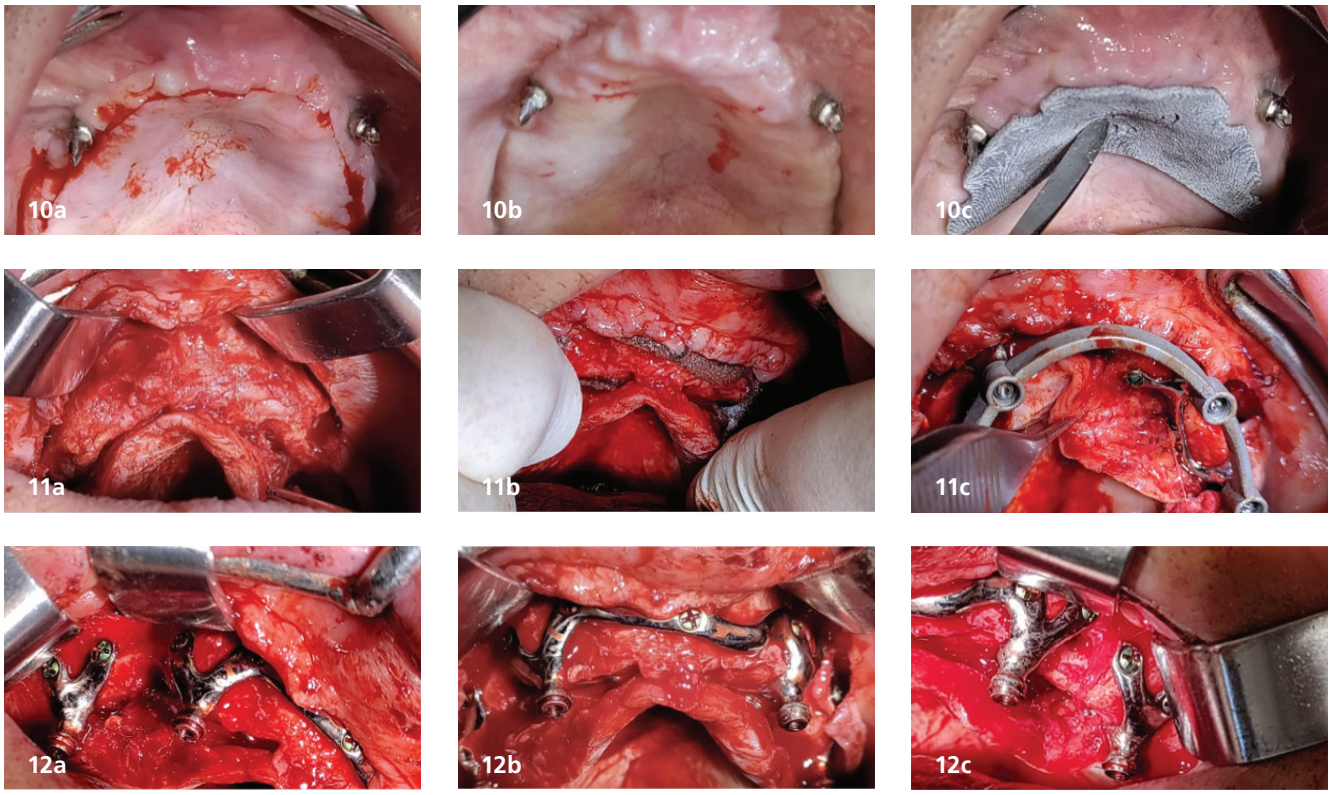


Fig. 10: Using the "3D flap" device, we can more easily make the incision corresponding to the future positioning of the prosthetic connections. **Fig. 11:** With the prototype of the implant, we can minimise the reflection of the periosteum and preserve the existing vascularisation as much as possible.**Fig. 12:** The subperiosteal implant in place: the strips adhere closely to the bone surface and all the screws are in place.

called the "emergence screw", is also available in the kit. This screw has a different shape, thread pitch and is 0.4 mm wider. A 2 mm longer screw must be used. Thus, a deep, half thickness incision must be extended along the entire contour of the implant to achieve passive repositioning of the flap. This is the main management to avoid primary exposure of the implant strip. Finally, a suture can be applied, initially using single stitches as follows: first a loop around each prosthetic platform, then the conventional stitches along the entire contour. Finally, a second continuous suture can be used to help the previous suture to minimise the effects of microswelling during the first ten days after surgery.

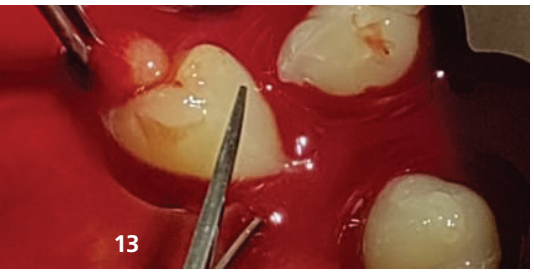


Fig. 13: The use of PRF membranes improves the soft-tissue healing, maximising new local vascularisation and neo-angiogenesis.

In addition, using a centrifuge (Duo Quattro, Intra-Lock System Europa), four L-PRF-derived membranes are placed under the flap corresponding to each prosthetic connection (Fig. 13). This additional precaution is particularly recommended in patients who are heavy smokers, if they are treated anyway. At the end of the previous procedures, after checking the occlusion and finishing in the laboratory, the temporary bridge is placed (Fig. 14). A panoramic (Fig. 15) and/or CBCT (Fig. 16) image is always taken immediately after surgery to confirm the close relationship between the implant structure and the bone. Immediate loading is one of the keys to success. The subperiosteal implant and its screws must be loaded immediately to heal together over time. Conventional recommendations for immediate loading of the implant were given to the patient. The clinical picture with and without the provisional 27-month post-op is also documented here (Figs. 17 & 18).

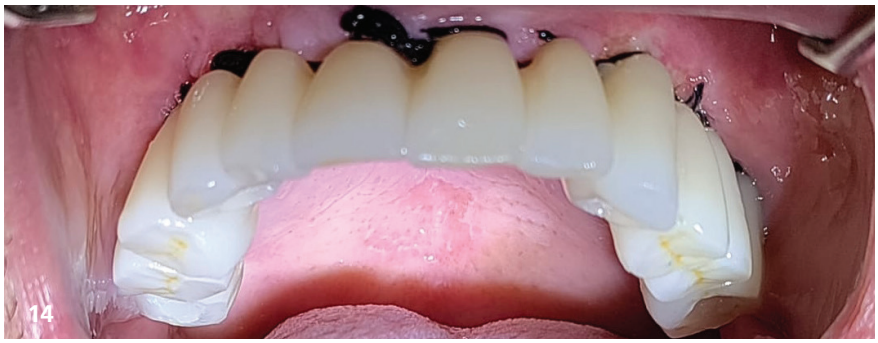
Discussion

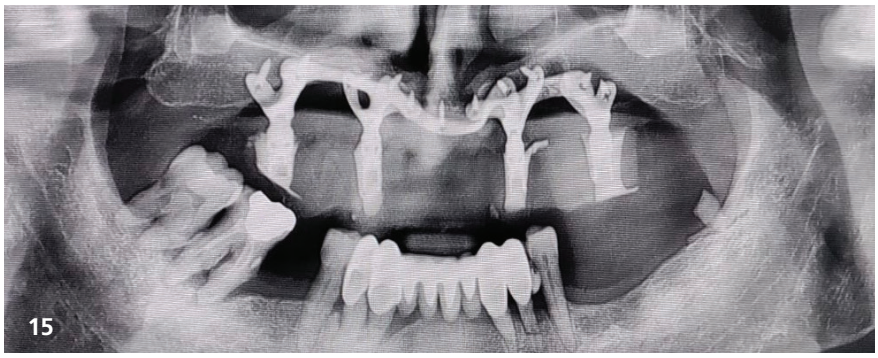
This report documents the use of a digitally manufactured subperiosteal implant for the rehabilitation of advanced atrophic maxillae. This implant allows immediate loading, avoiding invasive procedures such as bone grafting or complex implantation through the zygomatic arch. Other surgical approaches are not considered indicated for the treatment of 5/6 Misch classification, especially in a fully edentulous patient. Subperiosteal implants were first described in 1943 by Dahl in Sweden.[19] However, these implants were associated with high complication rates such as soft-tissue dehiscence, implant superinfection and mobility, and ultimately implant loss. Immediate loading is one of the keys to the success of the subperiosteal implant

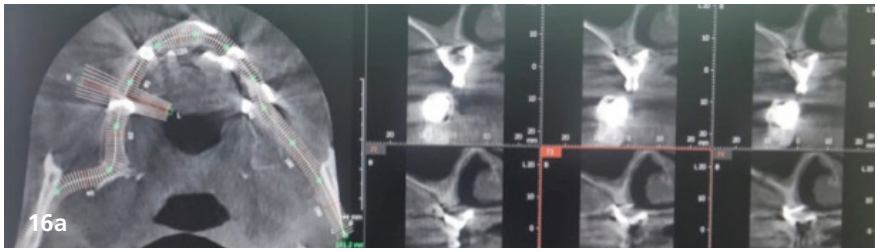
protocol. All screws and the structure must be loaded together immediately after placement. The subperiosteal implant is not "initially bone-retained" and we will never get osseointegration[22] even if the implant is made of grade 5 titanium alloy. Osseointegration is a natural healing mechanism whose principles have been well documented for many years around an unknown object. The subperiosteal implant is a completely different approach and the success is obtained respecting other factors as already widely published from the 70's.

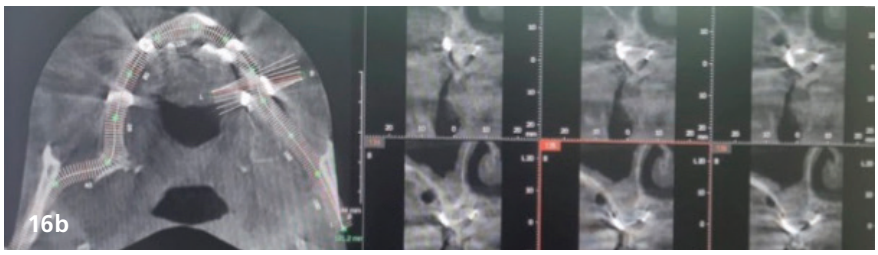
New acquisition techniques, improved hardware and software, computer-aided design and selective laser melting allow the customisation of implant therapy, improving several aspects such as only one surgery, accuracy of framework, screws, surgical management, titanium alloy, surface treatment, prosthetic connection. Compared to alternative modern designs, the SP4 custom subperiosteal implant of the present study, due to its high precision, does not rely on bone undercuts to achieve primary stability. The entire digital workflow allows the implant structure to be planned along the natural pillars of the maxilla, which favours the distribution of forces. The final design is therefore very minimal, without the need for the implant abutments to be extensive or invasive over the bony structure and surrounding muscle and soft-tissue envelope. The smaller the design, the more predictable the placement of the implant would be, speeding up the surgery and reducing the risk of infection, as well as facilitating removal in the unfortunate event of implant failure. For a more effective summary, it is also worth recalling the innovative devices introduced by the SP4 protocol and their benefits.

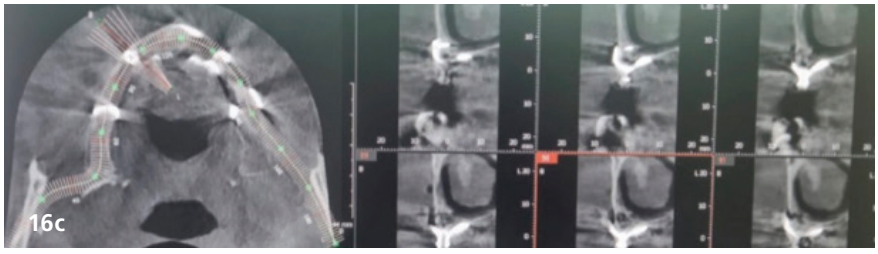
The 3D flap guide for incision predicts the prosthetic emergence of the prosthetic











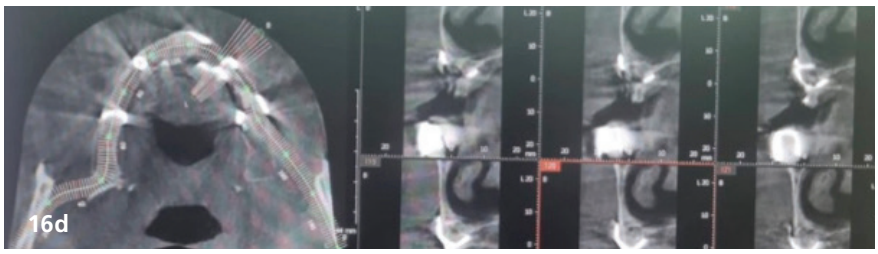


Fig. 14: Immediate loading with screw-retained reinforced restoration. **Fig. 15:** Panoramic radiograph immediately after implantation. **Fig. 16:** CBCT post-implantation: the intimate contact between implant and bone is clearly visible.

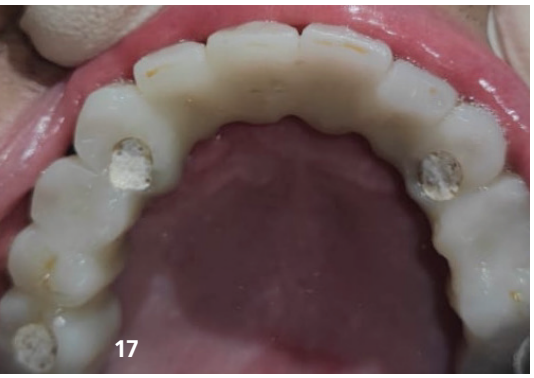
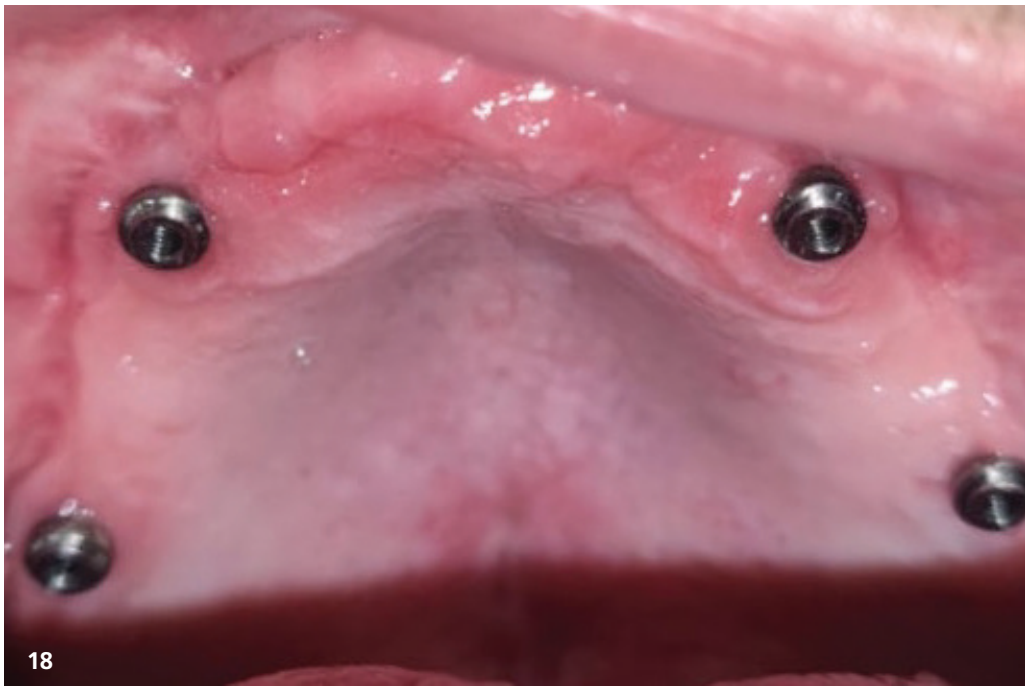


Fig. 17: Clinical view of final bridge in place 27 months after loading. **Fig. 18:** Clinical aspect of soft-tissue healing two years after surgery.



connection, avoiding additional incisions and preventing premature exposure of the implant. The "implant prototype", used in conjunction with a more conventional anatomical replica, is both extremely useful in exposing only sufficient bone surface for implant placement, avoiding unnecessary periosteal reflection and achieving faster and more predictable healing. The entire digital workflow of the accurate design allows to obtain even a customised shape to envelop the head of the screws. The self-tapping screws give the clinician an easier and faster placement in a critical part of the surgery. In addition, gain an excellent stability over time, as it seems after four years of follow-up of 68 consecutive clinical cases treated with SP4 implants from 2019. The "3D bridge" helps the clinician during the placement step to maintain a correct position and immobility during screw insertion. Its "double use" as a rigid framework of the temporary bridge is a way to drastically reduce the time of the immediate loading protocol while maintaining the optimal fit with the prosthetic platforms of the implant. In conclusion, considering all the details presented so far, the SP4 implant protocol seems to be a probable approach for the treatment of the advanced resorbed jaw with an implant-supported fixed restoration.

Conclusion

Despite the inherent limitations of a case report, this study showed that 3D digitally fabricated subperiosteal implants could be a valid solution for the rehabilitation of the atrophic maxilla, avoiding long, invasive and/or dangerous surgeries.

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References

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