

WORKFLOW COMPARISON IN SUBPERIOSTEAL IMPLANTOLOGY: TRADITIONAL VS. DIGITAL APPROACHES

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ABSTRACT

Aim of the study This study aims to conduct a comparative clinical and technological examination of standard analogue versus digital subperiosteal implants for treating patients with severe alveolar ridge atrophy. **Materials and methods** Two illustrative clinical workflows were analysed to demonstrate the practical and technological evolution of subperiosteal implantology. The first workflow involved the fabrication and placement of a cast cobalt-chromium implant using a traditional analogue method, which included direct intraoperative bone impression and a two-stage surgical protocol. The second workflow followed a fully digital approach, integrating CBCT-based virtual planning, CAD/CAM design, and fabricating a custom titanium framework via selective laser melting (SLM), executed in a single surgical stage. The comparison focused on surgical procedures, laboratory methodologies, and postoperative outcomes to highlight the key differences between the two approaches. **Results** Several surgical procedures and manual intraoperative adjustments were necessary for the analogue workflow to guarantee implant fit. The healing process was uneventful; however, the period of treatment was prolonged. The digital method allowed for quick prosthetic temporization, decreased surgical morbidity and allowed for the perfect preoperative design. The titanium framework exhibited superior anatomical conformity and patient comfort. The material properties and surface finish of the digitally fabricated implant were exceptional. **Conclusions** Digital subperiosteal implants signify a substantial advancement in the treatment of individuals with severe bone atrophy. In contrast to the conventional analogue method, the digital protocol provides enhanced accuracy, less morbidity, and faster prosthetic recovery. The clinical benefits of incorporating cutting-edge materials and new technology into contemporary oral implantology are highlighted by these advancements.

Keywords: Subperiosteal implant, digital workflow, CAD/CAM, titanium framework, severe atrophy, selective laser melting, advanced biomaterials, CBCT planning

INTRODUCTION

In contemporary oral implantology, one of the most difficult cases is the rehabilitation of edentulous patients who have extensive alveolar ridge atrophy. Even if bone augmentation techniques have advanced significantly and endosseous implant options have become more versatile, a sizeable portion of patients still have clinical and anatomical constraints that make traditional implant therapy impractical (1).

Subperiosteal implants were first used in the 1930s as an alternative to endosseous implants for patients who had severe bone resorption. The early designs, created by pioneers like Muller (1937) and Strock (1939), showed promise in terms of mechanical retention but were linked to issues like poor osseointegration, bone resorption, and chronic inflammation. As a result, their use declined for several decades (2).

Subperiosteal implants have made a comeback thanks to recent developments in three-dimensional imaging, computer-aided design, and additive manufacturing. These implants are now made as unique digital frameworks that are adapted to the specific anatomy of each patient. The production of extremely accurate and stable subperiosteal implants with enhanced clinical predictability is made possible by technologies such as selective laser melting or milling of biocompatible materials, CAD software, and cone-beam computed tomography (CBCT) (3,4,5). At the same time, advanced titanium-based or titanium-zirconium (Ti-Zr) alloys, which provide better biocompatibility, mechanical strength, and resistance to corrosion and bacterial colonization, have replaced conventional Cr-Co alloys as the materials utilized to make these implants (6).

The article aims to provide a comprehensive clinical and technological review of the subperiosteal implant, comparing the classic analogue approach with the modern digital workflow. Two representative clinical workflows are presented to illustrate the evolution of subperiosteal implantology, emphasizing the procedural differences between analogue and digital approaches and highlighting the impact of advanced biomaterials and emerging technologies in the treatment of patients with severe alveolar ridge atrophy.

MATERIALS AND METHODS

Two subperiosteal implant workflows are compared in this study: an analogue procedure with direct intraoperative impression and two-stage surgery and a digital CAD/CAM-based protocol with single-stage placement. The illustrative clinical photos, which were chosen from a number of cases carried out by the same surgical team, are used to facilitate the comparative comparison of approaches and to document the standard procedural stages. These are shown as representative clinical

sequences rather than as long-term case reports.

In the pre-digital age, the analogue procedure, which uses a two-stage surgical approach, was widely employed. Clinical and radiologic assessments were typically used to confirm severe maxillary atrophy (Cawood and Howell Class V–VI), ruling out the possibility of sinus augmentation or endosseous implants.

The first surgical stage involved the elevation of a full-thickness mucoperiosteal flap (Fig. 1), succeeded by a direct impression (Fig. 2) of the exposed maxillary bone utilizing a high-viscosity impression material.

The analogue technique requires a wider and more exploratory flap to allow adequate examination and impression of the osseous anatomy, which is not completely known beforehand, in contrast to digitally guided procedures, which can be precisely localized based on preoperative CBCT analysis. To accommodate the future implant framework and facilitate tension-free closure, the flap was extended approximately 2–3 mm beyond the anticipated limits of the implant design, following standard recommendations for passive adaptation and optimal wound coverage (7).

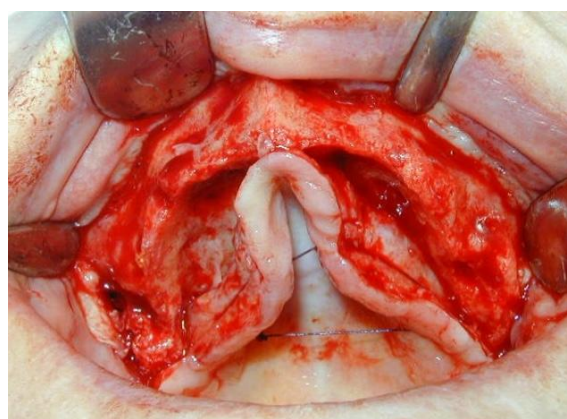


Figure 1. Intraoperative picture of bone exposure during analogue impression technique



Figure 2. Direct impression of the maxillary bone

A preliminary stone model was constructed for diagnostic evaluation and implant design.



Figure 3. A replicated cast model created from the bone imprint

During the laboratory phase, the subperiosteal implant was fabricated directly on a duplicated stone model. A wax model was fabricated to conform to the anatomical features and support regions of the maxilla. The pattern was subsequently invested and cast with a cobalt-chromium (Co-Cr) alloy in a regulated argon gas atmosphere, utilizing vacuum-pressure or centrifugal casting to avert oxidation and maintain the structural integrity of the framework.

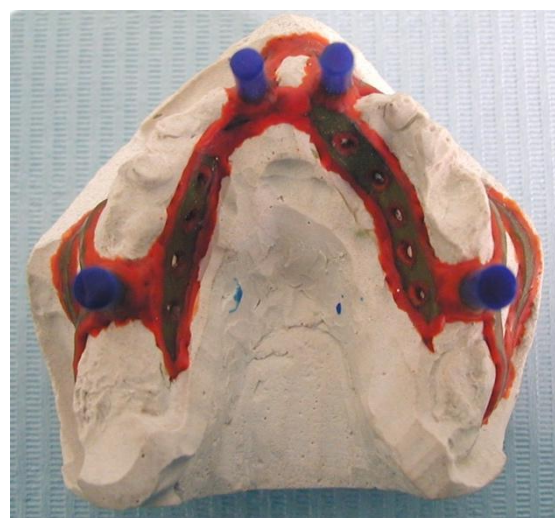


Figure 4. Hand-made wax-up design of subperiosteal framework

During the casting process, the argon medium minimized the incorporation of porosities or oxides, ensuring a clean, high-quality surface with good biocompatibility (8,9,10). After casting, the framework was polished, cleaned, sterilised and ready for surgical implantation.

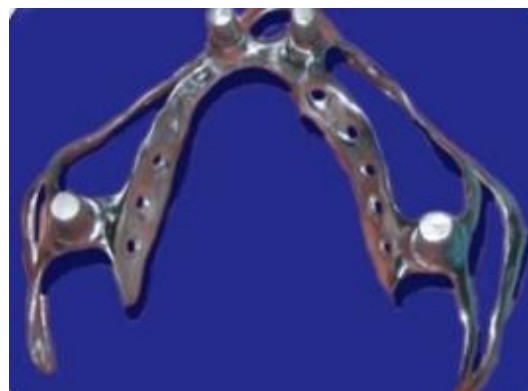


Figure 5. The implant after polishing and finishing

The second surgical stage was conducted three weeks after the initial impression. A new full-thickness flap was elevated to reveal identical bone landmarks, and the prefabricated implant was placed and stabilized through soft

tissue tension and anatomical alignment (Fig. 6).



Figure 6. Placement of analogue subperiosteal implant on the maxillary bone

Minor adjustments were made with bone graft material (lyophilized allograft) to optimize implant fit. The flap was sutured tightly to ensure mucosal sealing.

Nine days following the removal of the sutures, the prosthetic restoration was started, and two weeks later, a temporary fixed prosthesis was supplied (Fig. 7). The definitive prosthesis was affixed four weeks subsequently. The patient was assigned to a 6-month recall protocol for dental hygiene and occlusal management.



Figure 7. Temporary fixed prosthesis

The digital workflow uses current planning and fabrication techniques to create a personalized implant based on three-dimensional patient data. An

edentulous maxilla CBCT scan is obtained and loaded into implant planning software (such as Implant Studio or Exoplan) (Fig. 8). To digitally construct the subperiosteal implant, a virtual model of the bone is created (Fig. 8), minimizing important anatomical structures and maximizing contact zones.

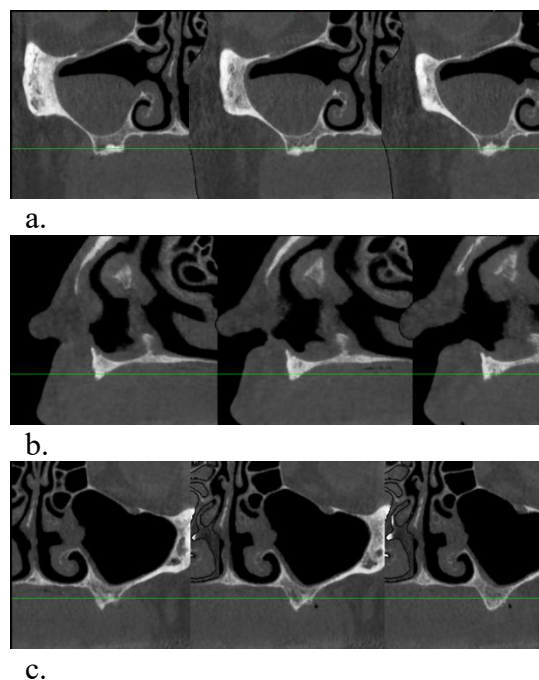


Figure 8. Preoperative CBCT sections showing severe maxillary atrophy (a. right molars region, b. frontal region, c. left molars region)

Using a titanium alloy (Ti-6Al-4V), the design was exported and produced using selective laser melting (SLM) (Fig. 9). Sterilization, ultrasonic cleaning, and polishing were all part of post-processing (Fig. 10).

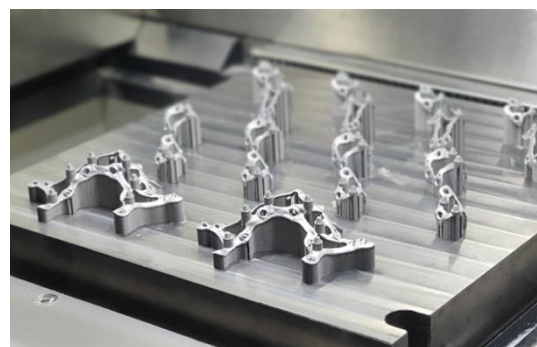


Figure 9. Selective laser melting (SLM) production of multiple custom subperiosteal titanium frameworks

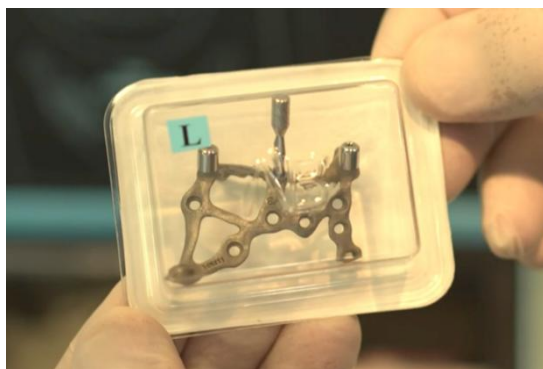


Figure 10. Custom-made titanium subperiosteal framework after fabrication and sterilisation

Prior to surgical placement, the custom framework adaptation was verified on a stereolithographic model of the maxilla to ensure passive fit (Fig. 11).



Figure 11. Verification of the custom framework adaptation on 3D-printed model

Under local anaesthesia, the surgery is performed in a single step. Only the areas required for seating have a small mucoperiosteal flap raised. There is no need for surgical correction because the implant is passively fitted to the underlying bone structure (Fig. 12).

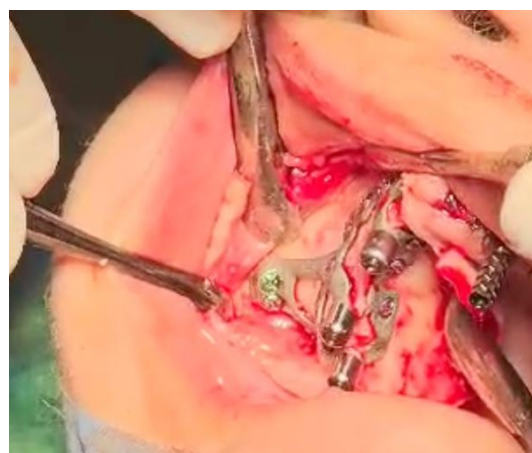


Figure 12. Implant placement during surgery

The flap is repositioned and sutured to achieve tension-free closure.

The transmucosal abutments in the framework were pre-designed, so a temporary restoration was provided right away or soon after.



Figure 13. Radiographic control showing provisional abutments connected to the subperiosteal framework

Following confirmation of implant integration and mucosal healing, definitive prosthetic work was finished at six weeks. A digital impression of the multi-unit abutments was then acquired to fabricate the final prosthetic restoration (Fig. 14).

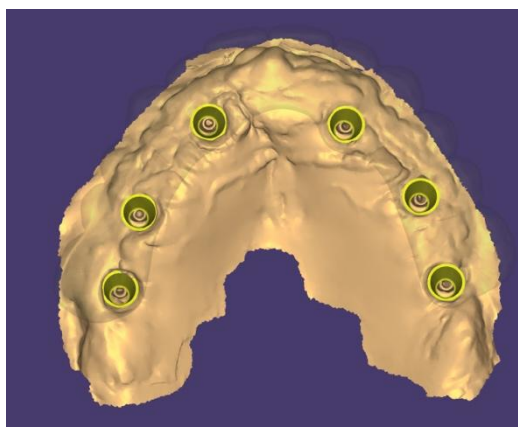


Figure 14. Radiographic control showing provisional abutments connected to the subperiosteal framework

A virtual wax-up of the definitive prosthesis was designed based on the scan data (Fig. 15), and the final restoration was delivered after verifying occlusion and esthetics (Fig. 16). During the first six months, a systematic follow-up regimen was put in place, which included monthly visits.

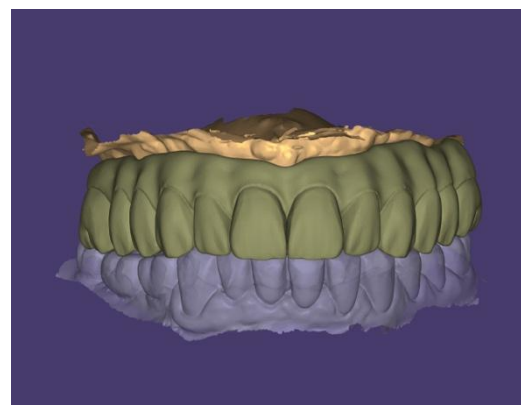


Figure 15. Virtual wax-up of the definitive prosthesis



Figure 16. Intraoral image of the final restoration in position

RESULTS AND DISCUSSIONS

successfully restore prosthetic function in patients with significant maxillary atrophy. Significant disparities were noted in process efficiency, surgical morbidity, prosthesis timeframes, and precision. The analogue case required two distinct surgical procedures: the initial for intraoperative bone impression and the subsequent for implant placement, with a minimum interval

of three weeks between them. This method extended treatment duration and invasiveness, perhaps resulting in higher soft tissue trauma and patient pain. Intraoperative problems encompassed accurate re-exposure of the osseous surface and guaranteeing passive fit of the cast framework. Minor errors were rectified with particulate allograft and precise modification throughout the surgical procedure.

Parameter	Analogue Workflow	Digital Workflow
Number of surgeries	2 (impression + placement)	1 (combined)
Treatment duration	4–6 weeks	2–3 weeks
Fit accuracy	Manual adjustment intraoperatively	Pre-validated digitally
Risk of impression errors	High (manual)	Minimal (CBCT-based)
Material used	Co-Cr alloy (cast)	Ti-6Al-4V (SLM)
Immediate temporization	Optional, often delayed	Routinely feasible
Patient morbidity	Moderate	Low

Notwithstanding these constraints, the implant exhibited stability, and the prosthetic repair advanced without issue. In contrast, the digital case necessitated merely one surgical procedure. The bespoke titanium framework, preoperatively created using CBCT data and CAD software, exhibited precise and passive fitting with minimum intraoperative modification. This method decreased surgery duration, tissue handling, and postoperative complications. The closure of soft tissue was devoid of stress, and the healing process was unremarkable. The digital technique facilitated prompt prosthetic temporization, minimizing the edentulous duration, and improving patient comfort and acceptability (4, 11).

Even when done in ideal circumstances, such as argon-controlled settings, traditional casting techniques can result in surface irregularities and marginal misfits, and direct intraoral bone imprints involve the hazards of poor reproducibility and patient discomfort (9).

Selective laser melting (SLM) additive fabrication of titanium frameworks guarantees a high level of customization and biomechanical performance. These implants improve overall patient-centred outcomes by providing better adaptability to anatomical shapes, minimizing surgical trauma, and enabling immediate prosthesis repair (12).

When compared to conventional Co-Cr frameworks, titanium and Ti-Zr alloys utilized in digitally produced implants exhibit superior mechanical strength, corrosion resistance, and soft tissue integration. These frameworks are also at the forefront of developing implantable biomaterials due to their potential for surface modification and coating (e.g., TiO₂, antibacterial layers) (13).

Although promising, the digital workflow is highly dependent on industrial-grade additive manufacturing equipment, software availability, and high-quality

images. Widespread use may be restricted by

infrastructure and cost, especially in clinical settings with low incomes. Furthermore, standardization across various software and fabrication platforms is required, as there are currently few long-term comparison studies available.

The use of functional coatings to improve biointegration and lower peri-implant problems, automated occlusal simulations, and integration with artificial intelligence for virtual surgical planning are some prospects.

Conclusions

An important development in the treatment of patients with severe alveolar ridge atrophy is the transition of subperiosteal implants from analogue to digital workflows. Although the classic approach is still useful in some clinical settings and is a relevant historical technique, it is linked to greater invasiveness, technical unpredictability, and patient pain.

The digital protocol, on the other hand, provides a predictable, minimally invasive, and patient-centered alternative. It is powered by CAD/CAM design, additive manufacturing, and CBCT-based planning. Custom titanium frameworks made by selective laser melting enhance treatment effectiveness and functional results by enabling high-precision anatomical adaptation and supporting quick prosthesis repair.

In terms of materials, the transition from cobalt-chromium casting to titanium-based printed frameworks represents a paradigm shift in the selection of biocompatible, lightweight, and adjustable implantable materials. These advancements are essential to contemporary developments in oral implantology and demonstrate the wider effects of cutting-edge materials and new digital technologies.

Although access to digital workflows is still restricted in some clinical settings and long-term comparative studies are still required,

the integration of these technologies ushers in a new era in complex case management by increasing therapeutic options for

edentulous patients who were previously thought to be incurable through traditional means. The first conclusion.

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