Custom-made 3D printed subperiosteal implant for restoration of severe atrophic jaw: a case report

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In the last decades, considerable progress has been made in the field of oral implantology, regarding endosseous implants, especially through the changes brought by the digital revolution. Although their versatility and predictability has been proven over time through clinical studies and follow-ups, endosseous implants have certain limitations, mainly given by the patients' perspectives: the general state of health, bone supply, long osseointegration time, etc. Well-designed subperiosteal implants have been reported to function successfully for many years and came as an alternative to endoseous implants. The analog method of inserting subperiosteal implants has been widely discussed and used over time, and represents a well-defined protocol. However, the first surgical time, that of taking impression of the residual bone field, caused problems for the clinicians as follows: the trauma inflicted to the patient was greater as he was subjected to two surgical interventions instead of one(first for the impression of the bone and second for the insertion of the implant), the grip contraction of the impression material creates the possibility that the implant doesn't fit to the bone. Digital technology comes into our hands in order to solve this unpleasant situations, offering the possibility to design the future implant on the CBCT scan of the patient long before the surgery itself.

This case report reviews the design characteristics of 3D printed superiosteal implants, step by step procedure and its particularities compared with the analog method, the anatomy of the areas upon which the implants rest in the maxillae, based on recent research perfomed in Romania, in collaboration with AB Dental International (1).

Introduction

The use of endosseous dental implants to replace missing teeth has been a very predictable solution for many years and is now one of the most common techniques in dental rehabilitation. However, sufficient bone quantity and quality is required for implantation. In cases of severe bone resorption, bone regeneration techniques, zygomathic implants, nerve lateralization and sinus lift surgeries were proposed, but unfortunatelly these methods require more advanced surgical procedures, which may result in higher complication rates, morbidity, and longer treatment times.

Subperiosteal implants were first developed in Sweden at the beginning of 1940's and have been used ever since, with a decrease in popularity with the invention of the first endoseous implants by Branemark. Subperiosteal implants were custom-made based on an impression obtained in the stage I surgery and inserted below the periosteum and stabilised to the bone with mini-screws, then covered by the mucosa in the stage II surgery. Thus, the pacient was subject to two surgeries at an interval of 21 days. The subperiosteal implants were made of cobalt-chrome or titanium alloys and were connected to the prosthesis using trans-

mucosal abutments that emerged into the oral cavity. Their replacement or decrease in use was due to the complexity of the production process, the imperfect fit of the implant caused by relative instability of the impression material, the wide range of complications (2).

Different protocols have been proposed lately for subperiosteal implants, especially the ones 3D printed, but infortunately romanian clinicians need to collaborate with abroad factories or laboratories in order to treat these cases. Here, the authors present their experience with an innovative design of a customized subperiosteal implant manufactured by AB Dental International based on the CBCT scan of the patient.

Case history/examination

A 58 years old male patient with severe maxillary athrophy was referred to the clinic due to complaints of inappropriate masticatory and aesthetic function. He reported a mixed tooth-implant supported maxillary rehabilitation with five implants and two teeth which failed 3 years ago after more that 15 years of use due to peri-implantitis and mobility. Ever since, our patient has been wearing a removable acrylic denture. The pacient denied smoking habits or relevant systemic diseases. In order to decide whether he is a valid candidate for a subperiosteal implant or not, the patient was passed through the entire selection process which included: general examination, clinical local examination of the oral mouth, laboratory analysis and radiographs. The pre-operative laboratory analysis were slightly modified with a high value of the PDW (Platelet Distribution Width) which can indicate anemia or an infection in the body. Clinical examination [Fig. 1(a)](12) and orthopatomography [Fig. 1(b)](12) indicated a combined horizontal and vertical severe osseous atrophy, confirmed through cone-beam computed tomography (CBCT) [Fig. 2](12).

Note : In some areas, due to the severe bone atrophy, oro-sinusal communications covered only by the mucosa were evident on the CBCT scan, in which case the patient's removable denture functioned as a protective ,,shield".

The cone-beam computed tomography has confirmed an inflamtion of the sinus mucosa due to odontal causes (infections associated with the previous teeth) and the severe lack of alveolar bone in all the maxillary regions that could be seen in the preliminary radiographs. The highest points of the residual bone were found, firstly, as it can be observed on the CBCT, in the third molars region both sides [Fig. 2(a) and 2(b)](12) with dimensions ranging between 2.4 and 7.2 mm in height and 6.6 and 10.2 mm in width in the first quadran and between 4.8 and 10.2 mm in height and 5.4 and 9.6 mm in width in the second quadran.

Implant placement in the posterior region of the maxilla, the distal area of the maxillary alveolar process, which corresponds most frequently to the position of the third molar, has been suggested by many authors as an alternative to bone grafting. The posterior maxillary region typically has type III or IV bone quality, consisting of thin cortical bone and low-density trabecular bone. Primary stability is adversely affected by this. Due to inadequate primary locking, as well as short implants having unfavourable biomechanics, this region tends to have low success rates. Therefore, clinicians face a challenge in rehabilitating this area (3).

The second area where we could measure some significant alveolar bone is the second molars region both sides [Fig. 3(a) and 3(b)](12) with dimensions ranging between 2.1 and 2.7 mm in height and 10.8 mm width in the first quadran and between 3.0 and 3.9 mm in height and 9.3 and 9.9 mm in width in the second quadran.

As it can be observed in the CBCT scan, in the first molars region both sides, the residual alveolar bone height is either less that 3.0 mm or unsignificant [Fig. 3(a), Fig. 4(a)](12), making implant placement without lateral window sinus lift impossible. In the first quadran, it is important to notice the abcence of the cortical vestibular bone and the oral comunication with the maxillary sinus, closed only by the mucosa (an where we previously mentioned that patient's removable denture functioned as a protective "shield").

As it can be observed in the figures above [Fig 4, Fig. 5 and Fig. 6](12), the other areas of alveolar bone have no significant dimensions that could be useful for a complete implant-prosthetic rehabilitation. Thus, the possible initial treatment plan proposed was bilateral window sinus lifting with delayed implant placement after 8 – 10 months from the initial surgery and guided bone regeneration for vertical and horizontal

deficiency in the frontal area. During these 8 – 10 months of healing, the patient was to be only aesthetically rehabilitated with a removable prosthesis and the prognosis was reserved. Because he has high functional and aesthetic requests, and due to the fact that he has already been edentulous for 3 years by now, we had to find a more appropriate treatment solution.

NOTE: THE MEASUREMENTS ON THE CBCT ARE MADE IN 1:1 SCALE, BUT THE IMAGES ARE MAGNIFIED FOR A BETTER VIEW.

Methods

Using the following protocol, maxillary custom-made implants were proposed, with an innovative design, including areas of endosseous support for adequate osseointegration:

Stage 1(2 months preoperative) – CBCT and Laboratory analysis

Presurgical implant imaging assessment includes all radiologic examinations performed previously, as well as new radiologic examinations chosen to support the implant team in formulating a definitive and comprehensive treatment plan for the patient. The goals of this phase include all surgical and prosthetic information needed to determine the amount, quality, and density of bone; the association of critical structures with the proposed implant sites; and whether or not disease is present at the proposed surgery sites (5).

It has been observed that a significant proportion of patients with a generally satisfactory dental history who have undergone laboratory screening have been found to have undetected systemic diseases, ranging from 12% to 18%. These disorders may have an impact on the implant surgery protocol or the likelihood of long-term success. The most common clinical laboratory tests are based on blood samples taken from the urine and venous system. These tests may include a CBC (complete blood count), a BMP (Basic Metabolic Panel), a Comprehensive Metabolic Panel (CMP) and bleeding disorder tests like PT (Prothrombin Time) or PTT (Partial Prothrombin Time). An A1c can also be obtained if a patient has prediabetes or diabetes, as this test measures how well the patient is managing their diabetes. (5).

Stage 2 (1 month preoperative) – Preoperative CBCT and custom-made implant design

The resulting DICOM data was used for reverse planning. Custom-made implants were designed by AB Dental International with inputs from the surgeon [Fig. 7(a) and 7(b)](13). Implants were designed with a 0.7 mm thickness to adapt to the maxillary buttresses through fixation with twenty-eight 2 mm×7 mm osteosynthesis screws.

Stage 3(2 weeks preoperative) – Custom-made subperiosteal implants manufacturing

The implants were manufactured by a direct metal laser sintering using EOSINT M 280 machine. It specifically produces top-quality metal parts on the premise of three-dimensional CAD information – completely naturally, in only a couple of hours, and with no require for other devices (4).

The system is alternatively prepared with a strong state laser of either 200 or 400 watts. This laser gives an outstandingly highquality radiation and stable execution. The Laser Power Monitoring (LPM) makes it conceivable to control all this during the building process. Beside an optimized Gas Management System this ensures ideal and steady handling conditions for highest and consistent part building qualities. The system works in both protective nitrogen and argon environments. This allows the system to process a wide range of materials: from light metals to stainless and tooling steel to super alloys. The plates were polished on the surface that contacts soft tissue. The surface that contacts bone was left rough (4).

To ensure a very smooth process of the surgical stage and to provide the clinician with all the necessary tools, the implants were delivered by the manufacturing company within a complete box full of the needed accessories for our procedure [Fig. 9(a)] (9):

1) a 3D printed polymer model useful for the clinician to establish the outline of the flap elevation which must be 3 – 4 mm away from the outline of the implant design;

2) sterilized 3D printed implant;

3) fixation screw driver with handle and fixation screws;

4) healing caps;

5) prosthetic components for overdenture restoration/prosthetic components for screw retained restoration as transfer abutments, connection abutments, analogs;

6) demineralized bone matrix ready to use withourt hydration or mixing;

Stage 4 – Surgical procedure

Surgery was performed under local anesthesia [Fig. 10](11) and inhalation sedation with permanent monitoring of vital functions, after a complete pre-opperative evaluation by the AIC (anesthesia and intensiv care) doctor. The patient was instructed to administer himself orally amoxicillin 875 mg + clavulanic acid 125 mg every 12 hours for two days prior to surgery.

A crestal incision was performed from tuberosity to tuberosity, with one relieving incision in the midline. Buccal and palatal flaps were raised, exposing the anterior nasal spine, the pyriform apertures, the canine fossae, the zygomatic buttresses and the posterolateral maxillae. Drawing the incision line must be done with a firm movement (for a good elevation of the mucoperiosteum), thus offering increased comfort to the clinician during the medical procedure, by the fact that the bleeding is minimal, a good post-operative healing is ensured (dehiscences are avoided, which at least in the case subperiosteal implant represents an element that can compromise its integrity).

In cases with severe bone atrophy, we can meet two types of mucosae: 1) residual hypertrophic mucosa, with low resilience, very loose, which must be adjusted intraoperatively becuase it has poor vascularity and is very reactive or 2) residual thin mucosa, which can cause difficulties in rounding the edges of the wound. In this case, the mucosae has been reduced during surgery.

The next step after elevating the flap is represented by the placement of the implant itself, after this was removed from the sterile storage box [Fig. 13](11). The implant has a position of maximum intimacy with the residual alveolar bone, intimacy that must be followed, identified and exploited.

The first ostheosynthesis screws that are fixed are those at the extremities of the implant. The initial tightening is not definitive, but gradually, manually.

The flap was closed through multiple single knot ties [Fig. 16](11) done with a synthetic suture, manufactured by polymerising propylene [Fig. 15] (10). The suture is hydrophobic, it absorbs practically no water and is chemically inert. It ensures excellent know security and has a consistently high tear resistence, property which helps us prevent the dehiscences. It is ideal for skin or mucosa suture, where an excellent cosmetic result is critical (6).

Prosthetic impressions were taken immediately after closure, and prosthesis was successfully adapted in the same day, prior to patient discharge. Patient's old removable denture was used as a provisional, and was padded in office. Thus, the patient being used to it, a much easier transition was endured. After it has been adapted and the abutments were placed, the denture was temporarilly cemented.

Discussion

In the last decades, although a decrease in the number of edentulous patients could be observed, their number still remains high, and with the increase in life expectancy, their need to replace lost teeth also rises. Furthermore, studies show that 1 out of 5 seniors aged 65 or more lost all his teeth. These being said, clinicians must offer viable treatment solutions to patients' problems.

Endosseous implants have been and still are a suitable solution for those missing teeth, but unfortunatelly in cases with severe bone atrophy they have their limitations. As an alternative, more that 50 years ago, the subperiosteal implant was designed to fulfill this acute need for bone support and has been used ever

since. However, the subperiosteal implants were soon surrounded by multiple complications such as implant exposure/woond dehiscences, implant mobility/implant loss, lack of intimacy with the bone due to impression material instability, and of course their popularity decreased. Recently, dentistry has been going through a digital revolution. It's all about digital acquisition, better software, and more advanced fabrication. It's the start of a whole new world of fixed prosthetics, including custom implant therapy.

In their study, Cerea and Dolcini described a group of 70 patients who had received custom-made titanium subperiosteal implants made using direct metal laser sintering (DMLS), which demonstrated a survival rate of 95.8% and low complication rates over a 2-year follow-up period. They came to the conclusion that when endosseous implants could not be placed, custom-made DMLS subperiosteal implants could offer a viable alternative treatment method for prosthetic restoration of severely atrophic jaws (7,8).

Conclusion

Althought subperiosteal implants are no longer the only option to restore atrophic jaws, they still remain a less invasive solution. Their high success rates and predictability remain undisputed advantages and, along with the technological evolution and the imprint left by the digital revolution even the worst disadvantages are losing ground, so that the treatment period was reduced from two surgical interventions to only one and thus the physical trauma inflicted on the patient is minimal. By using digital technology, the clinician has the opportunity to foresee the final result of the treatment plan, to realize the design of the future implant based on a 3D model of the patient's anatomy, thus reducing almost to a minimum the possibility of error in execution. The important aspects that the clinician must continue to pay attention to are the healing stage and the complications associated with subperiosteal implants: dehiscences, implant mobility, framework fracture. These being said, the clinician's skills to propose, design and place a subperiosteal implant remain and for sure will be an important asses in any ideal treatment plan.

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