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CLINICAL PAPER

Bone and Skin-Supported Stereolithographic Surgical Guides for Cranio-Facial Implant Placement

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Abstract

Purpose Osseointegrated skin-penetrating implants enhance the retention and stability of the craniofacial prostheses and provide the long-term comfort. However, to determine the implant locations is a great challenge facing the surgeon. Implants may either be located in conventional manner or by STL generated surgical guides.

Materials and Methods Present study reports the CT based 3D virtual modeling, preoperative virtual planning and the implant placement by using a STL surgical guide, in an anotia case.

Results Employed materials and the methods facilitated the implant surgery while improving the operational security.

Conclusions CT based 3D virtual modeling of the surgical site, determining the implant locations virtually and the STL guided placement of the craniofacial implants, were found useful applications in order to facilitating the surgical intervention and providing prevention from complications.

Keywords Facial Prosthesis · Craniofacial Implant · Surgical Guide · Virtual Planning · Stereolithography

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Introduction

A trauma such as a traffic accident, gunshot or fire, and also the removal of a neoplasm, may cause defects in the head and face [1, 2]. They may also occur congenitally such as micro and/or anotia [3]. Defects and malformations of the face eventually lead to psychosocial hazards requiring rehabilitation. Plastic surgical reconstruction, or prosthetic rehabilitation may be used for this purpose [4]. Surgical reconstruction of a facial defect by using own tissues of the patient is primarily preferable. However, complex or large defects might not be reconstructed surgically. Additionally, optimal tumor aftercare in case of high risk of recurrence, local or general contraindications concerning procedures of surgery, damaged neighboring tissues due to the radiotherapy, poor general health condition, previously failed reconstructive procedures, rejection of the surgery by patient, high esthetic demands, the desire for quick rehabilitation and the palliatively operated patients are the other obstacles of the plastic surgery. Such defects should better be treated prosthetically [1, 4]. Facial prostheses are employed for this purpose.

Retention of facial prostheses can be established by anatomic, mechanic, chemical and surgical techniques [1]. Additionally, weight reduction by using hollow prosthesis may contribute to the retention [5]. Already existing anatomical structures or undercut areas of the defect are employed to retain the facial prostheses conventionally [6–8]. Mechanical retention obtained by eyeglasses, straps or headbands, has been used for a long time [9–11]. Skin adhesives have also been used for chemical retention in spite of their limitations [12–14]. Surgical retention provided by surgically created retention elements such as skin-penetrating osseointegrated implants, has been used since 1977 and are the most favorable retention sources for facial

prostheses nowadays [1]. Employment of the osseointegrated implants to retain facial prostheses and their success were reported in related literature [3, 4, 9, 15–23].

The basic principles of the surgical application of facial implants were described mainly in two phases [1]. Both of these phases can be performed either in one operation or in two separate interventions.

The advantages of the implant support were described as reliable retention, facilitated insertion of the prosthesis by patient himself, fewer skin complaints with the help of adhesive-free wearing and the long-lasting thin and transparent edges in comparison with the glued ones [23]. Contrarily, implant support for a facial prosthesis also has some disadvantages. Inability to maintain peri-implant hygiene leads to peri-implantitis, which may result in misfit of the prosthesis or even implant failure [3]. Absolute contraindications of the facial implantation were reported as severe psychiatric disorders and cachexia. Lack of hygiene, drug and/or alcohol addiction and minor psychiatric disorders are merely relative contraindications and should be assessed individually [1].

Osseointegrated implants are used in different regions of the face to fix a facial prosthesis. However, they should correspond to the requirements of the facial prosthesis. Placing of the implants and production of the polydimethyl siloxane (PDMS) prosthesis were described in case-reports [2–4, 9, 18–27]. Locations of the implants for forthcoming ear prosthesis may easily be planned conventionally [1, 3]. On the other hand, implant locations can be planned virtually [26, 28, 29]. For this purpose, implant site may be scanned radiographically or optically [30–32] and modeled digitally [33–35]. Surgical guides produced with stereolithographic (STL) techniques in order to the computerized tomography (CT)-based planning, may be employed in surgical intervention [36–38].

CT based virtual planning of the implant locations and the surgical placement of implants with the help of a STL surgical guide in an anotia case, were evaluated in this paper.

Case Report

A 17-year-old female patient with an unsuccessfully reconstructed left ear was referred to the department of prosthodontics from the department of plastic and reconstructive surgery (Fig. 1). Ear has been lost 2 years ago in a traffic accident and consequent surgical interventions were not be able to establish proper esthetics. A CT scan of the head was obtained initially. 2D stacked uncompressed CT images were imported to the software (ProPlan CMF, Materialise NV, Leuven, Belgium), and three-dimensional (3D) virtual model was created. Implant locations were determined on this virtual model (Fig. 2). Images of the required slices were evaluated meticulously by using the rotating, zooming and panning functions of the software. Host bone dimensions were measured point-to-point, either on 2D slices or 3D virtual model. Tubes in 3.5 mm internal diameter were planned on the implant locations in order to guide the implant drill. Borders and the anatomical landmarks such as eye and nostril openings of the skin-supported mask were also designed virtually. A rod-

Fig. 1 Reconstructed left ear after a series of plastic surgical interventions

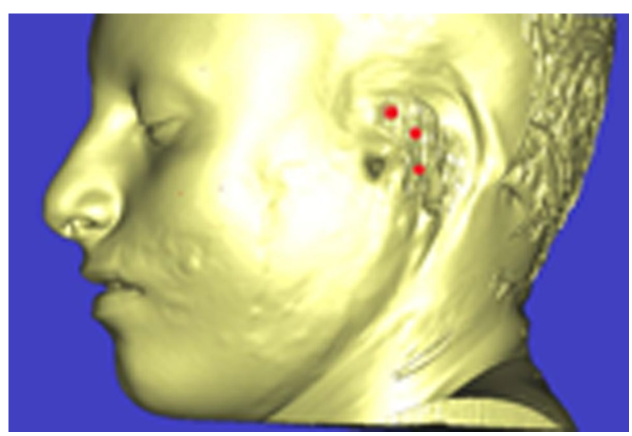

Fig. 2 Determination of the implant locations on the three-dimensional (3D) virtual model

connection between the drill-guides and the mask was also added in order to complete the virtual designing of the skin-supported surgical guide. The processed data was transferred to a triangulated file by using the STL module (ProPlan STL^{+} Module, Materialise NV, Leuven, Belgium). Obtained STL file was transferred to the rapid prototyping system (ProJet 3D Systems, Rock Hill, SC, USA) and the skin-supported surgical guide was computer-aided-designed and computer-aided-manufactured (CAD–CAM) by using this system. Guide was tried preoperatively and autoclaved prior to the surgical intervention (Fig. 3).

Operation was planned into two stages: the first stage consists in essence of the drilling of the host bone and the insertion of the implants into their individual sockets. The second stage was planned for reduction of the soft tissue cover, achieving a hair-free surrounding skin as well as the insertion of the percutaneous abutments through the skin. Stages were planned at 8 weeks of interval.

Patient was taken to the first stage of the operation under general anesthesia. Incision was performed after the planning and marking. Previously created unaesthetic ear structure was removed (Fig. 4). Afterwards, the full-thickness skin flap was released and the implantation site of the host bone was exhibited (Fig. 5). Surgical guide was applied to the face. Attention was paid to the facial landmarks such that eye and nostril openings were in correct position while the drill guiding tubes were in contact with bone surface (Fig. 6). Starter drill was inserted through the guiding tubes consequently (Fig. 7) so that implant locations and the angles were clarified. Surgical guide was taken out and the implant sockets were completed with final drill (Fig. 8). In order to protect the bone tissue from the surgical trauma, new and sharp drills at a low speed of 1500 rpm and under extensive cooling through flushing with Ringer's solution, were used. Self-threading shoulder type three extraoral implants (EO Implant, Institut Straumann AG, Waldenburg, Switzerland), 3.3 mm diameter and 4.0 mm length, were screwed mechanically under torque control with 20 Ncm (Figs. 9, 10). Skin flap was thinned, reposed and sutured. A week after, surgical area was controlled and the sutures were cut-off.

Fig. 4 Surgical removal of the unaesthetic ear structure

Fig. 5 Full-thickness skin flap and the exhibition of the implantation site of the host bone

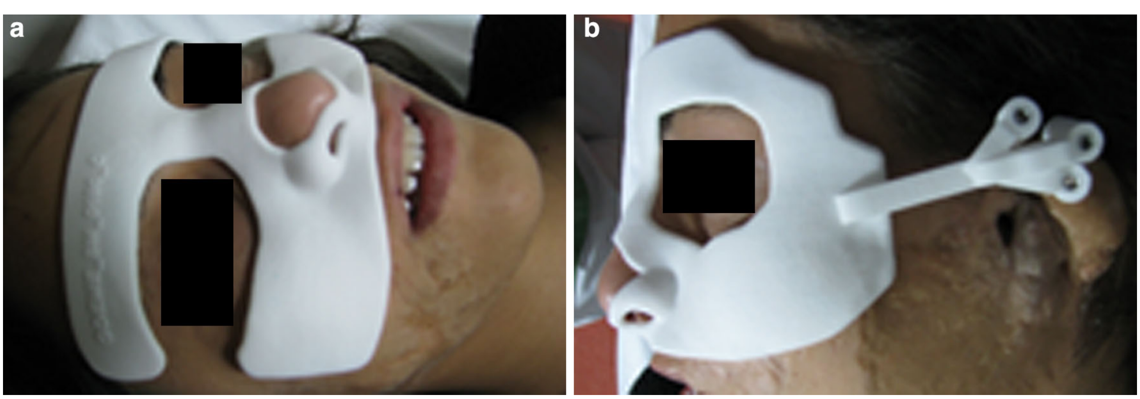

Fig. 3 Stereolithographic surgical guide in situ. Note the anatomical landmarks such as eye and nostril openings of the skin-supported mask being kept open (**a**) and a rod-connection between the bone supported drill-guides (**b**)

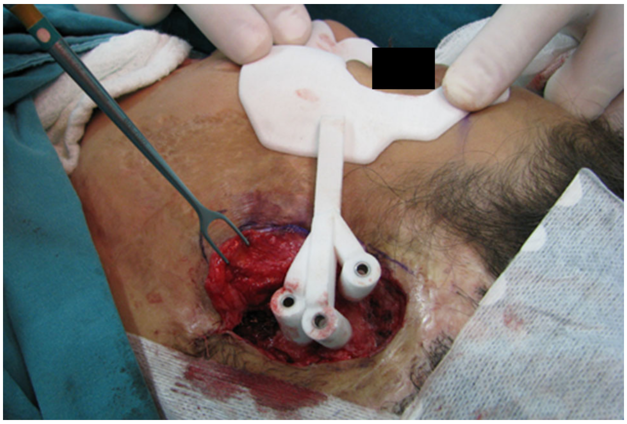

Fig. 6 Application of the surgical guide. Attention was paid to the facial landmarks being in correct position while the drill guiding tubes were in contact with bone surface

Fig. 7 Initial drilling through guiding tubes

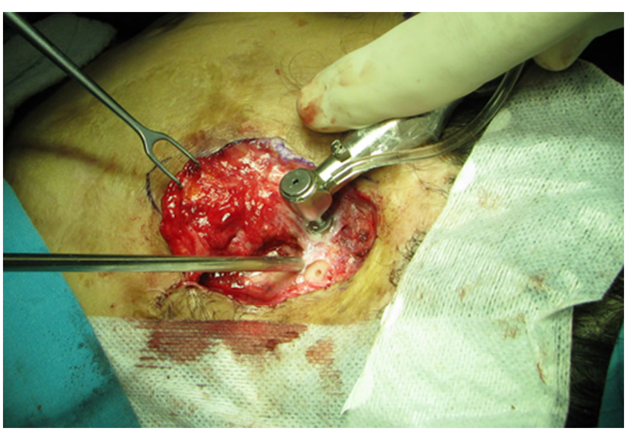

Fig. 8 Finishing of the implant sockets with final drill

Six weeks after the first intervention, patient was taken to the second stage operation under local anesthesia. Implants were uncovered and the abutments (Cone Abutment, Institut Straumann AG, Waldenburg, Switzerland)

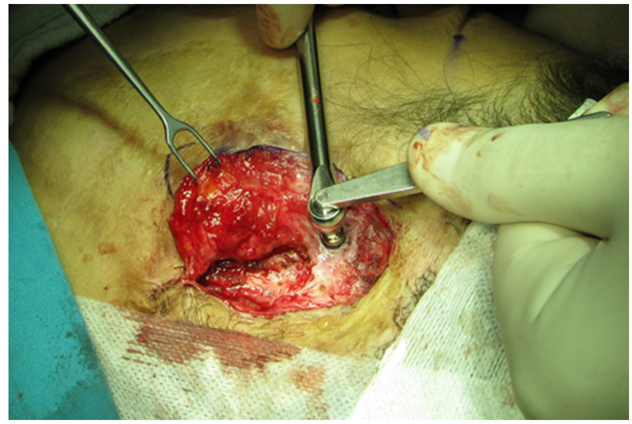

Fig. 9 Mechanical screwing of the implant under torque control

Fig. 10 Self-threading shoulder type extraoral implants in situ

were screwed onto the implants as to project outwards through the skin. A gauze pack was stripped upon the surgical site as to press the thinned skin to the bone.

After the completion of the soft tissue healing and the establishment of the final tissue contours, bar-retained ear prosthesis from polydimethyl siloxane material, was made (Fig. 11).

Discussion

Retention was mentioned as a challenging problem confronting the facial prostheses in recent studies. Facial prostheses retaining to anatomical and/or surgical undercuts; also retaining with mechanical aids have been still reported [3, 6–11]. Hatamleh et al. [12] reported that, ocular prostheses included in their study were entirely retained by undercuts. Chemical retention was advised especially for orbital and nasal prostheses [12]. Contrarily, they are not advised for large midfacial defects because the skin adhesives might be precluded due to the presence of

Fig. 11 Bar-retained ear prosthesis from polydimethyl siloxane material

persistent moisture and saliva [14]. Skin adhesives have some disadvantages such as decrease in efficacy on continual use, possibility of allergenic response, poor dexterity hampering proper positioning of the prosthesis, debonding due to the head movement, perspiration, daily removal for hygiene and poor home-care [3]. Surgical retention, has been provided by skin-penetrating osseointegrated implants [1]. Numerous case presentations might be found in the literature about the facial implants [3, 4, 9, 15–17, 19, 20, 22, 26]. They were mostly auricular prostheses. Orbital and nasal prostheses followed consequently [12, 16, 17].

Insertion of the implants and the insertion of the percutaneous abutments were performed in two separate interventions in this case and the implant locations were planned virtually prior to the first stage. Conventionally, mastoid bone is known as the most suitable implant site for an auricular prosthesis. According to the analog watch projected to the right ear to superimpose the meatus onto the center, implants should be located between 9 and 11 o'clock at a distance of 2 cm from the meatus [1, 3]. This location corresponds roughly with the antihelix and thus provides sufficient space for the abutments of the auricular prosthesis. On the other hand, virtual planning of the implant locations was described in some reports [26, 28, 29, 36, 37].

Preoperative planning of the craniofacial implants was reported as important to eliminate the subsequent improper placement of the implants [36–38]. Maintaining of the CT based 3D virtual model of the craniofacial structures as well as the defect area has been reported as the preliminary requirements for the surgeon to select an appropriate site for patients whose anatomy does not allow placement of implants conventionally [32–35].

The surgical guide obtained with the help of this virtual model may be used in surgical interventions [26, 29, 36–38] so that the surgeon can visualize the correct placement of implants directly on the bone [36]. For this reason, surgical guides were known to provide the prevention from the unexpected surgical complications related to the anatomical specifications [1, 26, 37, 38].

STL has been used in production of the surgical guides [37, 38]. This method consists of the production of the 3D objects by using data transferred CT image files. Craniofacial defect and neighboring hard and soft tissues, prototypes of the prostheses and surgical guides may be manufactured with stereolithography [29, 30, 33–35, 37]. The data about hard and soft craniofacial structures and the defect may be acquired by CT, magnetic resonance imaging and optic scanning of the surface by using various light sources [31, 32].

In the present study, implant locations were planned virtually with the help of CT images. The used software, data transfer tools, the STL module and also the rapid prototyping system were found successful in production of the surgical guide. The surgical guide facilitated the surgical intervention and provided prevention from unexpected complications. Computer-guided implant locations have not reflected the conventional locations. This observation supports the importance of the virtual planning of the facial implant locations.

Conclusions

Under the lights of the related literature, following conclusions were drawn:

CT based virtual planning and the STL guided placement techniques were useful applications for cranio-facial implant surgery. They facilitated the surgical intervention and provided prevention from unexpected complications.

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