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New series of surgical design for anterior maxillary reconstruction with deep circumflex iliac artery flap

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Abstract

Microsurgical reconstruction for anterior maxillary defects presents a surgical challenge. The objective of this study was to ascertain the feasibility of a new series of intraoral surgical approach using deep circumflex iliac artery (DCIA) flap to achieve functional reconstruction for anterior maxillary defects. Two male patients with anterior maxillary defects (Brown Class IC) were treated in this study. Both patients underwent computer-assisted maxillary reconstruction with a DCIA flap (with pedicle positioning laterally to the bony flap) using intraoral anastomosis techniques. The overall DCIA flap survival rate was 100% and mucosa was all healed uneventfully. One patient received dental implantation and loaded with prosthetic superstructures. Both patients were satisfied with their postoperative oral function and appearance. This study illustrated a new and feasible series of surgical design for anterior maxillary bone defect reconstruction with DCIA flaps and intraoral anastomosis assisted by digital techniques.

KEYWORDS

anterior maxillary reconstruction, computer-assisted surgery, deep circumflex iliac artery flap, intraoral anastomosis, microsurgery

1 | INTRODUCTION

Maxillary defects often occur due to oncological resection, trauma, and infection. For maxillary defects with poor soft tissue conditions, the vascularized bone flaps along with dental implants are the most commonly recommended ones to achieve functional reconstruction.[1,2] However, reconstruction of anterior maxillary defects (class IC according to Brown's classification) involves several unique characteristics when compared with other maxillary defects. (a) Traditionally, the pedicle is placed internally to the bony flap to be protected, and this requires a larger space for the vessel pedicle to pass through the receipted vessels. In contrast, due to relatively restricted space for anterior maxillary defects, the pedicle is more likely pressed if placed internally. (b) Due to restricted distance between the anterior maxilla and the submandibular vessels, the traditional methods of anastomosis require a longer pedicle of the bony flap to reach the recipient vessels, increasing the difficulty as well as the risk of the operation.

Dr. Bimeng Jie and Dr. Xiaoming Lv contributed equally to this work and share the first authorship.

Due to the abovementioned characteristics, reconstruction for anterior maxillary defects is worthy to be served as an isolated research topic. Since 2008, Gaggl et al have been using medial femoral condyle (MFC) flap together with intraoral anastomosis to achieve reconstruction for severe atrophy and defects of anterior maxilla.[3-5] Nevertheless, the position of the pedicle still remained ambiguous and the shape of the flap was unsatisfying, and nonvascularized bone grafts from the anterior iliac crest were sometimes required to fill the gaps of the reconstructed segments.[6]

Due to sufficient bone height and alternative contours, deep circumflex iliac artery (DCIA) flap has been favorable in the reconstruction of alveolar ridge.[7] Thus, this study aimed to solve the drawbacks of the methods mentioned above by presenting a new series of surgical design using DCIA flap to achieve functional reconstruction for anterior maxillary defects. The key points of the procedure were as follows: (a) The DCIA flap provides sufficient bone volume; (b) the pedicle was placed laterally/labial to the bony flap to avoid being compressed; (c) computer-assisted surgery was used to individually reconstruct the alveolar ridge and reduce the soft tissue attachment of the flap; and (d) intraoral anastomosis was applied to solve the problems of pedicle length.

2 | MATERIALS AND METHODS

2.1 | Patient characteristics

From November 2018 to December 2019, two male patients (aged 19 and 53 years) with anterior maxillary defects were treated in the study at the Peking University School and Hospital of Stomatology in China. The inclusion criteria were as follows: patients with anterior maxillary defect (class IC, according to Brown et al[1]); and the possibility of maxillary reconstruction by using a DCIA flap. Of the two patients, one had motor vehicle accident (MVA) and the other had crash by falling on stones. The time from the first-stage debridement to the second-stage reconstruction surgery was 6 and 8 months, respectively. All patients had accompanied defects of anterior maxillary dentition and soft tissue (Figure 1). The characteristics of the two patients are shown in Table 1.

This study was approved by the ethics committee of the Peking University School and Hospital of Stomatology (PKUSSIRB-201949138), and the patients signed the informed consent agreement of clinical images and data for medical use.

Before surgery, preoperative maxillofacial and pelvis noncontrast enhanced CT scans were acquired (helix with 1.25-mm slice thickness; BrightSpeed 16-slice CT scanner, GE Healthcare, Buckinghamshire, UK). The CT data in Digital Imaging and Communications in Medicine (DICOM) format were imported into ProPlan CMF software (Materialise NV, Leuven, Belgium). The maxilla and the iliac bone (HU threshold: 226 ~ 3071) were segmented and separately converted to an STL file format. The range of defects was then identified.

2.2 | Methods

2.3 | Virtual surgical planning

The location and the orientation of dental implants were designed to restore the normal occlusion for future prosthodontics. According to the virtual design of the dental implants, virtual reconstruction was done to restore the exact shape of the dentition arch (Figure 2). The mesiodistal, bucco-oral, and craniocaudal diameters were measured to their fullest extent. The iliac crest was designed to reconstruct the curve of alveolar ridge. The internal side of the iliac crest was designed for reconstructing the labial surface of the anterior maxilla. The 3D-printed resin guide was then designed to guide the harvesting and molding of the DCIA flap.

2.4 | Surgical procedure

After general anesthesia, patients were laid in supine position. Deep and tongue retractors were used to gain exposure and maintain adequate mouth opening. (Video S1 in supplement materials).

2.4.1 | Step 1: Exposure and preparation of recipient bed and vessels

A vertical incision of the buccal mucosa to the vestibular groove was created by avoiding injury to the parotid duct. After raising the myomucosal flap of the buccinators, the facial artery and vein were then exposed and dissected for over a length of 4 cm to allow adequate vessel diameter. The facial artery and vein were prepared until it could be transposed to the anterior border of the ramus for later anastomosis (Figure 3A,B). The recipient bed including the maxillary defect was exposed and debrided through a vestibular approach, connecting the vertical incision of the buccal mucosa (Figure 3C).

FIGURE 1 Preoperative findings. A, Oblique frontal view of patient No. 1 showing collapse of left naso-labial region. B, Intraoral view showing defect of anterior maxilla, mucosa and dentition arch. C, CT scan showing defect of anterior maxilla, mucosa and dentition arch (red square) [Color figure can be viewed at wileyonlinelibrary.com]

2.4.2 | Step 2: Harvesting of the DCIA flap guided by 3D-printed surgical guide

DCIA flap was simultaneously harvested followed the methods described by Brown et al[8] and Zheng et al.[9] The skin incision was outlined that it was 2 cm superior to the connection of the pubic tubercule and the anterior superior iliac spine (ASIS). The external and internal obliques were elevated off the iliac crest while protecting the ascending branch of the DCIA. After the cut of the transversus abdominis was elevated, DCIA and deep circumflex iliac vein (DCIV) were dissected off the transversalis fascia. The ASIS was preserved to avoid the donor site morbidity. The 3D-printed surgical guide was then temporally fixed to the lateral side of the pelvic bone with osteosynthesis screws, ready for sawing. Iliac crest osteotomies were then performed under the guidance of the surgical guide according to the shape of the maxillary defect. External oblique muscle fascia was harvested with the flap and used for alveolar ridge lining (Figure 3D,E).

2.4.3 | Step 3: Positioning of the DCIA flap and the pedicle (key point)

In the traditional procedure, the inner table of DCIA flap was medially placed to protect the pedicle and the outer table was placed laterally to facilitate fixations, and this requires a larger space for vessel pedicle to pass through the receipted vessels. However, in this study, the iliac crest was placed inferiorly to conform the alveolar ridge and the pedicle was placed laterally to the flap. Due to accurate virtual design, the osseous flap was then positioned over and trimmed to fit the defect with limited monocortical screw fixations (Figure 3F).

2.4.4 | Step 4: intraoral anastomosis (key point)

The pedicle then naturally followed the vestibular groove to reach the recipient vessels of the buccal region, without any compression. Arterial anastomoses were completed between the flap artery and the facial or labial superior artery as end-to-end anastomoses. The venous anastomoses were made between the accompanying flap veins, and the facial vein or angular vein was made as end-to-end anastomoses in the same manner (Figure 3G). Excellent inflow and outflow were confirmed, and the external oblique fascia was closed with the overlaying mucosa (Figure 3H).

2.5 | Postoperative follow-up

All patients were followed up clinically and radiologically after 1 week, 3 months, and 6 months postoperatively by panoramic radiographs and CT scans. Complications at the recipient site (such as infections, iatrogenic facial nerve damage, and flap resorption) or at the donor site (such as bone fractures, hernia, and gait disturbances) were monitored and recorded. The accuracy of the virtual surgery was analyzed by comparing the postoperative 3D images and the virtual surgical plan (Figure 4).

3 | RESULTS

The mucosa showed well healing without any complication. Both patients had unrestricted mobilization postoperatively. No recipient complication or severe donor-site complication were observed during the follow-up. The pedicle was 4.9 and 5.6 cm in length, respectively. The average length and height of the iliac crest were 3.2 cm and 2.3 cm, respectively. The follow-up interval was 13 and 8 months, respectively. One patient received dental implantation and gingival grafting 6 months after undergoing the microvascular surgery and loaded with prosthetic superstructures. Both patients were satisfied with their postoperative oral function and appearance (Figure 5). Both patients showed satisfying repeatability between the postoperative CT data and the preoperative design.

TABLE 1 Demographic data and clinical characteristics of the patients

Patient No.	Age (y)	Gender	MOI	Time after injury (mo)	Defect range (cm)		DCIA flap size (cm)		Length of the pedicle (cm)	Accuracy of computer-assisted surgery (mm)	Dental implants	Follow-up interval (mo)
					Length	Height	Length	Height				
1	19	M	MVA	6	2.9	2.5	2.8	2.4	5.6	4.9	Yes	13
2	53	M	Crashing	8	3.4	2.1	3.6	2.2	4.9	4.5	No	8

Abbreviations: DCIA, deep circumflex iliac artery (supplies the iliac crest); M, male; MOI, mechanism of injury; MVA, motor vehicle accident.

4 | DISCUSSION

Anterior maxillary defects that result from tumor resection, trauma, and infection cause severe aesthetic and functional handicaps. The goal of the anterior maxillary reconstruction is to restore the nasolabial aesthetic appearance and create a stable pre-prosthetic framework for implant reconstruction. The 3D complexity of the bone framework, defects of the attached mucosa, and the aesthetic importance of the anterior dental arch present several challenges when the option of reconstruction is considered. Dental obturators and removable partial dentures have not been shown offering any significant advantage in aesthetics or mastication.[10] Transport distraction osteogenesis is reliable to obtain an ideal osseous form and height, but the technique is sophisticated and time consuming.[11] Nonvascularized bone grafts remain an excellent option for managing small bone defects that are surrounded by well-vascularized soft tissues. Unfortunately, the long-term durability is unreliable as the bone grafts undergo partial or subtotal resorption and may require future augmentation with additional bone. For segmental maxillary defects that are associated with soft tissue defects, composite vascularized flaps combined with osseointegrated implants were used to obtain reliable long-term results.[12-14]

Different from the larger ablative maxillary defects, the anterior maxillary defects have unique characteristics, and the traditional and unified methods for these were not considered appropriate. The reasons were as follows: (a) The traditional position of the pedicle is placed internally to the bony flap, and requires larger space for anterior maxillary defects. However, due to relatively restricted space for anterior maxillary defects, the pedicle is more likely compressed. (b) Restricted by the distance between the anterior maxilla and the submandibular vessels, the traditional methods of anastomosis require longer pedicle of the bony flap to reach the recipient vessels. This study was conducted in order to present a new series of surgical procedures to solve the particular problems associated with reconstruction of anterior maxillary defects.

Unlike ablative maxillary defects, the dimension of anterior maxillary defects is relatively small and irregular, remaining a challenge for positioning of the pedicle.

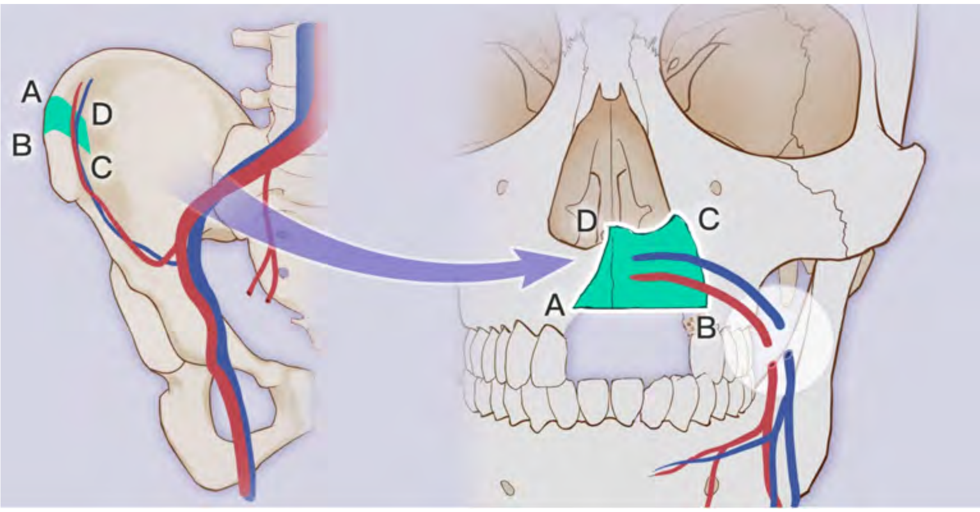

FIGURE 2 Schematic representation of preoperative virtual reconstruction of the defect using DCIA flap. The inner table of DCIA flap was put laterally to the defect. DCIA, deep circumflex iliac artery [Color figure can be viewed at wileyonlinelibrary.com]

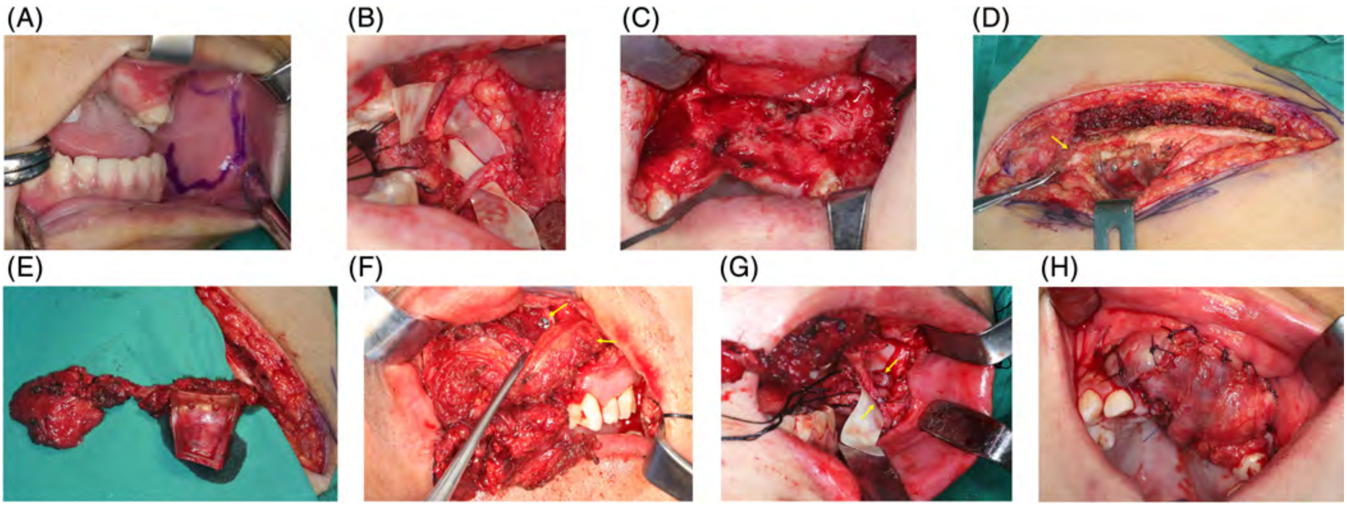

FIGURE 3 Intraoperative findings. A, Preparation of the recipient vessels. A vertical incision of the buccal mucosa was made. B, Facial artery and vein were exposed and prepared. C, Anterior maxillary defect was exposed and the transplant bed was debrided. D, DCIA flap was harvested and molded under the guidance of 3D-printed resin template. Surgical guide was fixed to the lateral surface of pelvic bone to assist osteotomies. ASIS was preserved to reduce donor-site morbidities (arrow). E. DCIA flap with external oblique muscle fascia island. F. The pedicle and inner table of DCIA flap were put laterally for fixations (arrow). G. The pedicle then naturally followed the vestibular groove to reach recipient vessels of the buccal region. Intraoral microvascular anastomosis depicting the facial artery to the deep circumflex iliac artery anastomosis (arrow) and the facial vein to deep circumflex iliac vein anastomosis (arrow). H. External oblique fascia was lined on the reconstructed alveolar ridge and closed with oral mucosa. ASIS, anterior superior iliac spine; DCIA, deep circumflex iliac artery [Color figure can be viewed at wileyonlinelibrary.com]

As shown in Table 1, the average length and height of the defect was 3.2 cm and 2.3 cm, respectively. If the pedicle was placed medially to the bony flap in traditional methods, the defect range would be inevitably enlarged and the pedicle would be compressed causing obstruction to the blood flow. In this study, the pedicle was placed laterally to the bony flap and positioned from the vestibular groove to reach the recipient vessels in the buccal region, following its natural path.

Most importantly, with intraoral anastomosis introduced by Gaggl et al,[4] the length of the pedicle was no longer a restriction. In this study, the average pedicle length of DCIA flap was 5.3 cm, which was considered adequate for intraoral anastomosis between the buccal phase of the facial arteries and the veins. Previous studies have also demonstrated feasible clinical results in using intraoral anastomosis with DCIA flap for maxillofacial reconstruction.[9,15]

Various donor sites have been used for harvesting microvascular grafts for anterior maxillary reconstruction.[2,16] Gaggl et al have used MFC flap together with intraoral anastomosis to reconstruct the severely atrophies and defects of anterior maxilla.[3] Considering the distance between the anterior maxillary defect and the

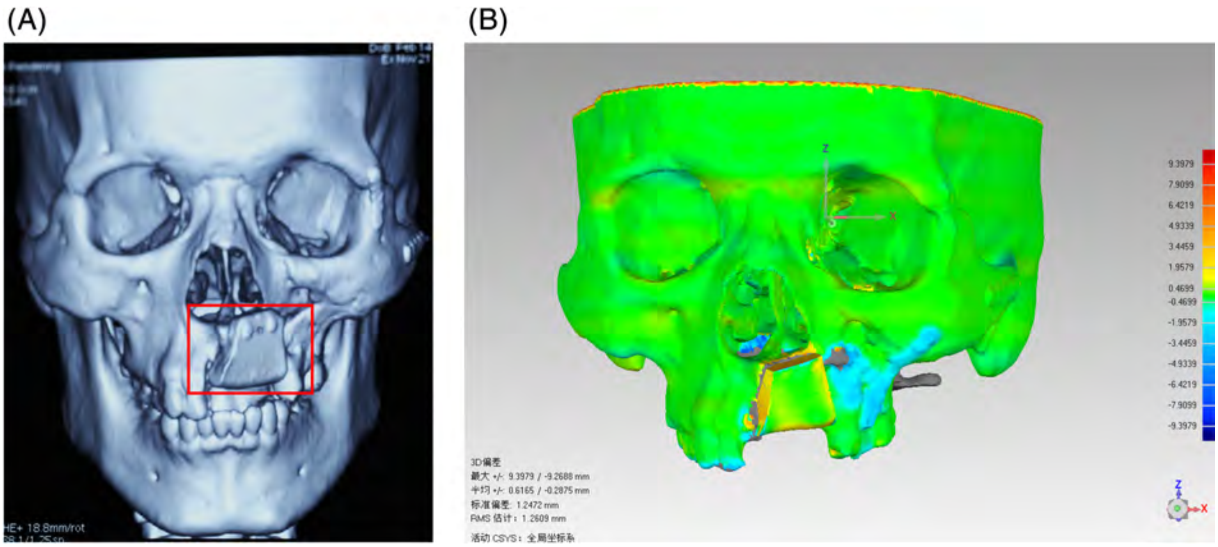

FIGURE 4 Postoperative findings. A, Postoperative CT scan showing reconstruction contour of the anterior maxilla (red square). B, Deviation between preoperative visual plan and postoperative result on color spectrum [Color figure can be viewed at wileyonlinelibrary.com]

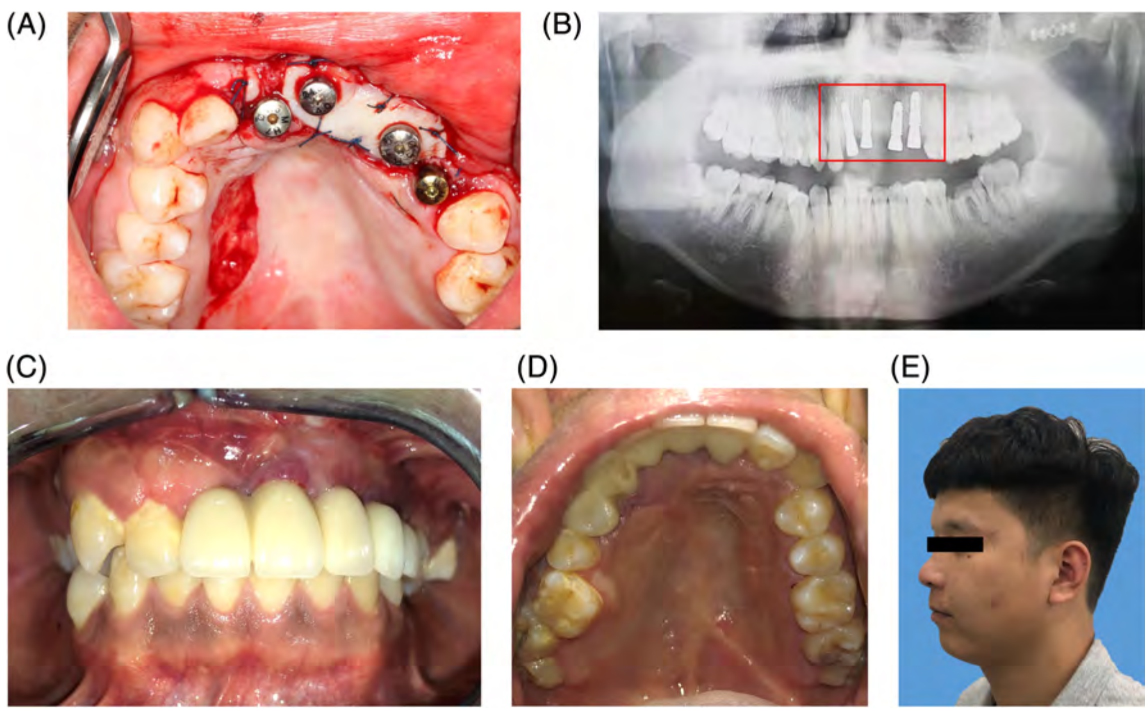

FIGURE 5 Second-stage procedures. A, Dental implanting and gingival grafting surgery 6 months after the reconstructive surgery. B, Postoperative panoramic radiograph showing satisfying locations of dental implants (red square). C,D, Postoperative intraoral occlusal view and bottom view of upper dentition showing satisfying occlusion and shape of dentition arch. E, Postoperative oblique frontal view showing satisfying naso-labial appearance [Color figure can be viewed at wileyonlinelibrary.com]

submandibular vessels, the use of free fibula flap (FFF) was also regarded as an optimal choice due to its long pedicle and stable skin island.[17] However, the straight contour of MFC flap and FFF were not considered appropriate to reconstruct the contour of the anterior dentition arch and the naso-labial appearance. Since 1996, Brown et al have stated that the DCIA with internal oblique remains the gold standard for maxillary reconstruction because of its sufficient bone volume for the osseointegrated implants and alternative contour of iliac crest that assists in forming the curve of frontier dentition.[13] In this study, the average bone height of DCIA flap was 2.3 cm, which was higher than the average bone height (1.3 ~ 1.5 cm) of the fibula flap reported in the previous studies.[18]

Unstable and thick soft tissue component is one of the drawbacks of DCIA flap put forwarded in the previous studies,[6] and this can be solved by computer-assisted techniques. Unpredictable and irregular anterior maxillary defect requires careful preoperative planning to ensure reconstruction results that are predictable. Computer-assisted techniques were commonly used in oral and maxillofacial reconstruction surgeries and proved to provide better clinical results than traditional surgery.[19,20] In this study, high aesthetic compatibility, high prosthodontic convenience, and low donor-site morbidity were the three factors that should be taken into consideration. According to the unaffected occlusion relationship, the locations and the orientations of the dental implants were initially designed. Virtual dentition arch curve was then designed and the majority of the matched portion of the iliac crest was selected as the target graft. ASIS was preserved to avoid donor-site morbidities. For better initial stability of the dental implants, iliac crest was inferiorly placed during the reconstruction of the alveolar ridge. 3D-printed resin surgical guides were designed to accurately transfer the virtual surgical plan to the actual surgery. Under the guidance of virtual surgical plan, the soft tissue volume can be reduced and the rigid fixations are possibly limited. In this study, both patients had no donor site morbidities and had satisfying occlusion and aesthetic appearance. The accuracy of computer-assisted surgery remained acceptable and equal to those of the previous studies.[9]

Owing to the relatively short follow-up time and limited number of patients, these findings should be cautiously interpreted. Due to limitations of 3D simulation methods, it is hardly possible to design the bone tissue and soft tissue reconstruction simultaneously before surgery. Future studies that focus on soft tissue prediction after bone defect reconstruction should be conducted.

This study illustrated a new and feasible series of surgical design for reconstruction of anterior maxillary bone defects with DCIA flaps and intraoral anastomosis assisted by digital techniques, and this resolves existing drawbacks and expands the range of existing methods for maxillary reconstruction.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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