Accuracy of Mandibular Reconstruction with a Vascularised Iliac Flap Using 3D Templates: a Systematic Review

Ting Wei LU[1], Wan Tao CHEN[1], Tong JI[1]

Objective: *To conduct a systemic review for guidance regarding the application of templates in mandibular reconstruction with vascularised iliac flaps.*
Methods: *By searching PubMed, EMBASE and the Cochrane Library and collecting relevant literature, information about the types and accuracy of templates was extracted. Data relating to surgical time were also included for further analysis.*
Results: *Eight studies were included. The data analysis showed that the accuracy of operations with templates was higher than that of conventional surgery. The mean deviation was between 0.70 and 3.72 mm. The operational time was shortened to 314.4 minutes and the graft ischemic time was reduced to 15.6 to 26.8 minutes. Application of functional or specifically designed templates can improve the accuracy and shorten surgical time.*
Conclusion: *Templates can increase the accuracy and efficiency of mandibular reconstruction with vascularised iliac flaps, which will benefit patients' prognosis and subsequent functional restoration. Further studies should be conducted into application of templates to improve the accuracy of reconstructions.*

Key words: *mandible reconstruction, template, vascularised iliac flap, virtual surgery*
Chin J Dent Res 2022;25(1):37–43; doi: 10.3290/j.cjdr.b2752689

The mandible accounts for the lower third of the maxillofacial region and plays an important role in maintaining face shape and function. However, factors such as inflammation, trauma and tumours lead to mandibular defects, which not only affect chewing and speaking but also have negative impacts on social life and mental health due to changes in appearance. Mandibular reconstruction is therefore crucial to improving patients' quality of life[1].

Bell[2] stated that the ideal conditions for bone transplantation should include stimulation of bone regeneration and replacement of lost bone tissue with new bone; no antigenic effect; the ability to rapidly regenerate blood vessels and establish blood circulation with the surrounding tissues; and the ability for the grafts to combine with the surrounding mandibular blocks. Autogenous bone transplantation is a suitable choice. Since Taylor et al[3] began to carry out ilium transplantation with deep circumflex iliac vessels in 1979, the combination of a vascularised bone flap and titanium plates in rigid internal fixation has become the gold standard for mandibular reconstruction. Among the different kinds of grafts, the fibula and ilium are widely used in mandibular reconstruction[4]. In most cases, the

1 Department of Oral and Maxillofacial-Head & Neck Oncology, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine; College of Stomatology, Shanghai Jiao Tong University; National Centre for Stomatology; National Clinical Research Centre for Oral Diseases; Shanghai Key Laboratory of Stomatology, Shanghai, P.R. China.

Corresponding author: Dr Tong JI, Department of Oral and Maxillofacial-Head & Neck Oncology, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, College of Stomatology, #639 Zhizaoju Road, Shanghai 200011, P.R. China. Tel: 86 21 23271699; Fax: 86 21 63135412. Email: jitong70@hotmail.com

This study was supported by the 'Star of Jiaotong University' Major Projects grant (no 20210103) to Wantao Chen and a grant from the Shanghai high level local university innovation team.

fibula is the first choice for repairing the mandible, and is superior to the ilium due to its long pedicle length and adequate skin paddle, which are characteristics that the ilium lacks. In some cases, however, especially for patients who do not need an extra long pedicle or who already have enough soft tissue, the ilium offers irreplaceable advantages. Compared with the fibula, the shape and contour of the iliac bone are more likely to match the curve of the mandible and it is rich in bone mass. It contains a generous cancellous and dense cortex of bone with an abundant blood supply, which is beneficial to dental repair after surgery[5]. Thus, under the premise of meeting the indications, considering the balance of function and aesthetics of the donor and recipient regions, a vascularised iliac flap is a good choice for reconstruction of mandibular defects[6].

From computer-aided navigation technology and surgical templates to recent virtual reality, augmented reality and mixed reality technology, an increasing number of high-tech techniques are being used in mandibular reconstruction[7]. In recent years, virtual surgery and 3D templates have been widely used in clinical practice. Surgeons use virtual surgery technology to design the operation plan and then apply it during surgery through the template. Many studies have reported that templates can improve the accuracy of mandibular reconstruction, but there is a lack of systematic clarification and analysis. As such, we systematically reviewed the research status and accuracy of templates in mandibular reconstruction with vascularised iliac flaps.

Operation process

The preoperative computed tomography (CT) scan of the maxillofacial and bilateral iliac regions is introduced into the 3D reconstruction software in DICOM format to form the 3D reconstruction model. The parts that do not relate to the surgery are removed and the lesion model is established. According to the region where the lesion is located, an osteotomy line is designed to simulate mandibular resection. For the fibula flap, a jig is made for guidance by taking a piece of bone that fits a straight line, which would put the plate in direct opposition to the bony surface. However, the iliac crest used for mandibular reconstruction has various curves in different patients, so it is difficult to use the aforementioned jig. Instead, we use the mirror function to duplicate the opposite mandible, fit the ilium to the defect and then adjust its position according to the occlusal relationship of the healthy side. Templates are designed based on the virtual surgery plan (VSP) and then printed into 3D models. Prior to the operation, the titanium plate is pre-bent according to the reconstruction model of the mandible to fit the morphology of the mandible on the reconstructed side. Thus, surgeons do not need to bend the titanium plate during surgery and only have to make small adjustments, which saves time.

After fully exposing the lesion area during surgery, the mandibular resection template is used to assist in the removal of part of the mandible. The reduction template can then help to restore the original position of the free mandibular blocks on both sides. The artery and vein are separated for vascular anastomosis. At the same time, according to the VSP, the vascular pedicle is separated, and the graft is cut with the help of transplant cutting templates. The size and shape of the graft are adjusted in advance according to the in-situ moulding templates. After the vascular pedicle is cut, it is anastomosed with the maxillofacial vessels. The bones from the donor and recipient areas will then be fixed with titanium plates and nails.

Materials and methods

To perform a systematic literature analysis, we referred to PubMed, EMBASE and the Cochrane Library and searched for keywords including computer-assisted, computerised, 3D, CAD, CAM, virtual, template, plate, guide, mandibular, mandible, ilium and iliac.

Studies were included if they met the following criteria:

- mandibular reconstruction;
- use of the vascularised iliac flap as a source of transplantation;
- use of templates in surgery;
- measurement data in the results.

The exclusion criteria included animal experiments, use of a fibula flap, inability to extract relevant data, and reviews, meetings, case reports, etc.

Results

The search strategy identified 354 articles in total, including 175 in PubMed, 13 in Cochrane Library and 166 in EMBASE. After removal of duplicate references, 248 articles remained. Based on the inclusion and exclusion criteria, a total of 17 articles met the requirements by referring to the title and abstract. After full-text reading, nine articles were excluded, three of which did not mention the measurement of accuracy, five did not use templates, and one used a fibula flap. Finally, eight studies and 149 cases were included for further analysis. The specific literature search process is shown in Fig 1.

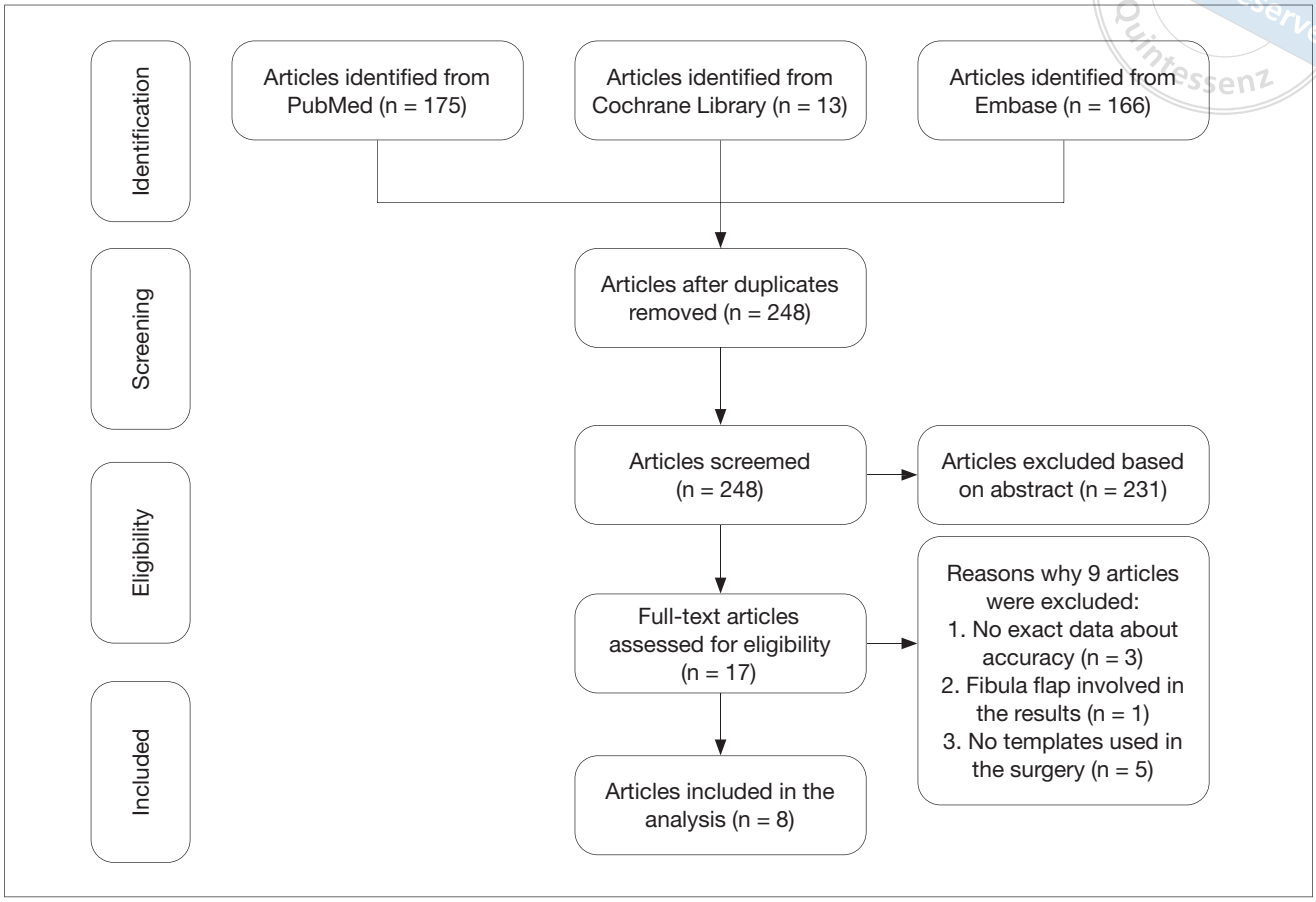

Fig 1 Flow chart for the article selection process.

Five articles designated control groups, and three of these (a randomised prospective clinical study[9] and two retrospective analyses[10,11]) compared the conventional surgical method with template-assisted operation. Three of the eight studies were retrospective analyses of mandibular reconstruction with templates, which were observational studies without a control group[12-14]. One article compared the accuracy of functional templates[15], while another compared simple templates with complex templates[16]. Both were retrospective analyses. Table 1 provides full details of the included studies[9-16].

In the included studies, 55 cases used the traditional operation method; thus, the reconstruction relied only on the experience of doctors without any computer-aided technology. The remaining 94 cases were completed with the aid of templates. According to the classification of mandibular defects set out by Jewer et al[8], there were 123 cases of L-type defects, five cases of H-type defects and one case of LC-type defects, while 20 cases were unclear. All template-assisted operations used the reconstruction model to pre-bend the titanium plate needed in the surgery (Table 1).

SurgiCase CMF (Materialise, Leuven, Belgium), ProPlan CMF (Materialise), 3matic-Software (Materialise), Geomagic Studio (3D Systems, Rock Hill, SC, USA) and Mimics (Materialse) are commonly used software for preoperative template design. The programs used for measuring accuracy in the present study were Geomagic and Mimics (Table 2)[9-16].

For the type of template, a mandibular resection template and a transplant cutting template were used in all eight studies. Five applied a reduction template to restore the relative position of free mandibular blocks at both ends after osteotomy[12-16]. In four articles, an in-situ moulding template was used to adjust the shape of the grafts in the donor area after harvesting the iliac bone and before cutting the vascular pedicle so that it could match with the broken end of the mandible, achieving a good repair effect[10,13,15,16] (Table 2).

Different methods were used to evaluate the accuracy of mandibular reconstruction. In one study, patients were asked to appraise the aesthetic situation of their appearance using a visual analogue scale[9]. Another article compared the displacement of the mandibular mid-

Table 1 Data of the included studies.

Study	Type	Conventional reconstruction (n = 55)	Template-assisted reconstruction (n = 94)	Defect type
Modabber et al[9]	Prospective cohort study	15	5	NR
Ayoub et al[10]	Retrospective cohort study	10	10	20 L
Zhang et al[11]	Retrospective cohort study	30	15	45 L
Shu et al[12]	Retrospective cohort study	NR	8	5 L, 3 H
Li et al[13]	Retrospective cohort study	NR	5	2 L, 2 H, 1 LC
Zheng et al[14]	Retrospective cohort study	NR	4	4 L
Lu et al[15]	Retrospective cohort study	NR	20: 10 with and 10 without in-situ moulding templates	20 L
Zho et al[16]	Retrospective cohort study	NR	27: 13 simple and 14 complicated templates	27 L

H, L and LC refer to the type of mandibular defect according to the classification by Jewer et al[8]; NR, not reported.

Table 2 Data relating to templates used in the surgery.

Study	Mandibular resection template	Transplant cutting template	Reduction template	In-situ moulding template	VSP software	Measurement software
Modabber et al[9]	*	*			SurgiCase CMF	NR
Ayoub et al[10]	*	*		*	ProPlan CMF, 3matic-Software	Geomagic
Zhang et al[11]	*	*			ProPlan CMF	Geomagic
Shu et al[12]	*	*	*		Mimics	NR
Li et al[13]	*	*	*	*	Mimics, Proplan CMF, Geomagic Studio	Mimics
Zheng et al[14]	*	*	*		ProPlan CMF	Geomagic
Lu et al[15]	*	*	*	*	Mimics	Mimics
Zho et al[16]	*	*	*	*	Mimics	NR

*Indicates that a specific type of template was used in the study. NR, not reported.

line, the height of the alveoli and the gap between the grafts and mandibular blocks by measuring the postoperative panoramic radiograph[16]. Five studies imported CT data into Geomagic or Mimics and integrated preoperative design with a postoperative 3D model[10,11,13-15]. The evaluation indices included the position of the osteotomy line and condyle, the curve of the lower edge of the mandible, the volume of the graft and the overall deviation before and after the operation. Two studies imported postoperative data into Mimics, comparing the differences in distance between condyles and mandibular angles and the deviation of the midpoint of the mandible to that of the condylar connection before and after surgery[13,15] (Table 2).

The mean deviation using templates was 0.70 to 3.72 mm before and after the operation, while that for traditional operations was approximately 2.45 to 5.50 mm. Comparatively, the accuracy of reconstruction with templates was higher. Among 64 patients who used reduction templates, the deviation before and after the operation was 0.70 to 2.70 mm. For the 30 cases without reduction templates, the deviation was 1.30 to 3.72 mm. Reduction templates can increase accuracy.

A total of five studies compared the operation time[9,10,13,15,16]. The mean surgical time for the conventional operation method was 525.2 minutes. After using templates, it was reduced to 314.4 minutes. Two studies compared the ischemic time from cutting the vascular pedicle of the graft to vascular anastomosis[9,10]. After using templates, the ischemic time was reduced by 15.6 minutes to 26.8 minutes compared with the conventional operation method. Microspheres can be classified as microcarriers or microcapsules according to their different cell-laden delivery applications[9]. Microcarriers are usually preformed into large amounts of tiny particles, then cells are loaded on their surfaces. On the contrary, microcapsules are prepared by mixing crosslinkable polymers with cells to encapsulate cells within them.

Discussion

For patients with mandibular defects, establishing how to better restore the integrity of their morphology and function is a major challenge. The optimal outcome of mandibular reconstruction is to make the midline axis symmetrical between the affected side and the healthy side[17]. To achieve this, the morphology of the healthy side is used by the mirror function as a reference for the reconstruction of the affected side. The accuracy of mandibular reconstruction refers to the difference between the shape of the mandible after the operation and the preoperative design. The smaller the deviation between the postoperative effect and the preoperative design, the higher the accuracy of mandibular reconstruction will be[18]. The accuracy of mandibular reconstruction could affect patients' appearance and occlusal relationship, as well as the subsequent functional restoration, such as oral dental rehabilitation and the suitable relationship between the temporomandibular joint and disc. Thus, the improvement in accuracy could not only improve the effectiveness of mandibular reconstruction but also benefit functional restoration. Many steps in the process of mandibular reconstruction affect its accuracy, particularly determining the range of osteotomy, adjusting the size and shape of the grafts and splicing and fixing the position of the mandible and grafts. It is difficult to achieve accurate results by relying solely on preoperative CT scans and doctors' experience. The application of computer technology in medical treatment can not only let doctors discuss and determine the surgical plan through virtual surgery but also produce templates through 3D printing technology to transform the VSP into an operation[19].

Fibula flaps are more widely used to reconstruct mandibles, but in some cases, vascularised iliac flaps are a good choice for mandibular reconstruction because of the advantages they offer in terms of shape and characteristics. Studies on the use of templates to repair mandibles with vascularised iliac flaps are currently limited; thus, this review aimed to compare the accuracy of this repair pattern and related evaluation methods. Randomised controlled trials (RCTs) are more scientific and rigorous; however, compared with drug interventions, RCTs are difficult to achieve in surgical interventions, and there are many related interferences. Therefore, no RCTs were included in our retrieval results, most of which are observational retrospective analyses. In addition, there is no uniform standard for evaluation of accuracy, and diverse methods were used in the different articles, so a meta-analysis could not be conducted.

In the eight studies included, three kinds of accuracy evaluation criteria were used: consulting the VAS score awarded by patients, measuring the panoramic radiograph and analysing 3D reconstruction models. The present authors believe that although patient feedback is very important, it is greatly influenced by subjective factors; directly based on the analysis of two-dimensional images, it will be affected by factors such as overlapping and blurring of images. The application of 3D reconstruction software for measurement is more objective and can be comprehensively evaluated in 3D scenarios, so this method of accuracy analysis is more reliable. The measurement indices using 3D reconstruction software can be divided into two categories. The first is importing CT data into Geomagic and comparing the overall or partial differences by fusing the 3D reconstruction models before and after surgery. The second is using Mimics to measure the distance between the points and compare the differences before and after surgery. The most important anatomical landmarks include the condyle, mandibular angle, chin and the curve of the lower edge of the mandible.

The type of mandibular defect also affects the accuracy of mandibular reconstruction. According to the classification set out by Jewer et al[8], four cases of LC-type defects made it difficult to form the chin because they crossed the middle line of the mandible and eight cases of H-type defects were less effective than L-type defects because they did not retain the condyle. Different types of defects are suitable for various reconstruction methods and different numbers of bone blocks. Thus, when evaluating accuracy, the impact of the types of mandibular defects should also be considered fully[16]. Although most of the eight articles included L-type defects, six cases involved chin or condylar defects; however, the accuracy of different types of defects was not discussed separately in the included articles, which could lead to deviation in our analysis.

When examining whether application of templates can improve the accuracy of mandibular reconstruction, studies that created traditional operation groups are more convincing than simple observation studies. Three of the included studies compared the reconstruction effect of the traditional operation method with that of using templates. By importing CT data before and after surgery into the software for 3D reconstruction and measurement, it was determined that the accuracy of template-assisted surgery was significantly higher than that of traditional surgery. Modabber et al[9] and Ayoub et al[10] compared the difference between the number of grafts harvested during the operation and that needed for actual reconstruction. They found that the length of

the grafts was 16.8 and 25.3 mm, respectively, which was longer than actual requirements, while the amount of bone harvested by the templates was basically consistent with the demands. Ghassemi et al[20] pointed out that there is a correlation between the amount of osteotomy in the donor area and postoperative complications. Unnecessary graft harvesting should therefore be minimised during surgery. The precise preoperative design and the assistance of templates can help osteotomy and transplantation processes to become more accurate.

In addition to templates, the use of computer-aided navigation technology in surgery is also common. Zheng et al[21] reported that the minimum deviation before and after surgery was up to 1.8 mm but was still higher than 0.7 mm when using templates. This indicates that preoperative virtual surgery with templates could achieve a better reconstruction effect.

The common templates are mandible resection and transplant cutting templates. These two kinds of osteotomy templates can indicate the osteotomy process in donor and recipient areas. They can not only help to resect the diseased tissues accurately but also reduce the complications caused by excessive osteotomy in the donor areas[22]. After using osteotomy templates, the accuracy of surgery can be improved from a minimum of 5.5 mm to a maximum of 1.3 mm. In addition, many functional templates are used in mandibular reconstruction. Usually, after mandibular osteotomy, the free mandibular blocks at both ends will be pulled by muscles so their relative position will alter, which makes mandibular reconstruction difficult. In one study, surgeons used a titanium plate to play a role in reduction[22]. It is pre-bent according to the reconstruction model to assist with reduction of the mandible, fixing the position of the mandible and graft according to the curve of the titanium plate; however, this method will cause a series of errors due to the displacement and deformation of the titanium plate. A reduction template can guide restoration of the mandible and graft during the operation to improve accuracy.

A total of 64 cases used a reduction template during surgery. The minimum deviation before and after the operation was 0.7 mm. Lu et al[15] compared the operation methods with and without in-situ moulding templates and found that using these templates to adjust the grinding of the graft in the donor area before cutting the vascular pedicle can improve accuracy, reduce graft ischemic time and shorten patients' hospital stay. On the basis of a simple template, Zho et al[16] added a specific design, for example locating holes on the template to accurately guide the repositioning of the titanium plates and bone blocks and to reserve a path for reducing bone loss when sawing. Compared with a simple template, a complex template with a specific design has higher reconstruction accuracy and shorter surgical time. These results suggest that functional templates and modified templates with specific designs can improve the efficiency and accuracy of surgery[23]. Thus, when designing templates, in addition to conventional osteotomy templates, some functional templates and an improved design can be added as required to simplify the operation steps and improve accuracy.

Application of templates simplifies the surgical procedure to a certain extent and reduces surgical time. However, Ayoub et al[10] pointed out that the total surgical time with 3D templates did not change greatly compared with traditional surgery. Although templates can improve efficiency, the process of fixing various templates during surgery increases the surgical time[24]. At the same time, Modabber et al[9], Ayoub et al[10] and Lu et al[18] pointed out that the ischemic time from cutting off the vascular pedicle of grafts to vascular anastomosis was reduced significantly after using in-situ moulding templates[25]. The shorter the ischemic time, the higher the success rate of transplantation[26]. Thus, templates, especially functional templates, play an important role in improving the prognosis of mandibular reconstruction and reducing complications.

However, application of templates causes some problems that may affect the accuracy of mandibular reconstruction. For example, it often takes a long time for the templates designed preoperatively to be delivered from the manufacturer to the hospital, and this will cause some tumours to grow quickly enough to exceed the range of osteotomies designed by the osteotomy template, resulting in the series of templates being unable to be used during surgery. In the process of positioning templates, ensuring their uniqueness is also a challenge that affects accuracy. In addition, the immediate repair effect will change during the process of patients' recovery. The influencing factors include changes in bone, muscle and soft tissue. Thus, personalised template designs should be generated that fully consider patients' actual situation; on the other hand, continuous improvements should be made to the design of templates, that is, making inaccurate template designs delicate, realising that the development and application of functional templates can improve accuracy, simplify operation steps and reduce surgical time.

Conclusion

Compared with conventional surgery, implementing preoperative VSPs with templates to present surgical plans during surgery can improve the accuracy of using

vascularised iliac flaps to repair the mandible and reduce surgical time. In addition, functional templates used to shape grafts before cutting the vascular pedicle could reduce ischemic time and postoperative complications. Many factors can affect the accuracy of the operation, so when designing templates, improvements should be made constantly to improve the prognosis of mandibular reconstruction.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Ting Wei LU performed the systematic analysis and wrote the article; Drs Tong JI and Wan Tao CHEN revised the manuscript. All authors read and approved the final manuscript.

(Received Mar 22, 2021; accepted Aug 11, 2021)

References

1. Hou G, Wu T, Shang Z, Shao Z. Application of digital surgery and additive manufacturing technology in reconstruction of mandibular defect with vascularized iliac muscle flap [in Chinese]. Zhongguo Shiyan Waike Zazhi 2020;37:635–638.
2. Bell WH. Use of heterogenous bone in oral surgery. J Oral Surg Anesth Hosp Dent Serv 1961;19:459–474.
3. Taylor GI, Townsend P, Corlett R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. Clinical work. Plast Reconstr Surg 1979;64:745–759.
4. Lyons AJ, James R, Collyer J. Free vascularised iliac crest graft: An audit of 26 consecutive cases. Br J Oral Maxillofac Surg 2005;43: 210–214.
5. Riediger D. Restoration of masticatory function by microsurgically revascularized iliac crest bone grafts using enosseous implants. Plast Reconstr Surg 1988;81:861–877.
6. Zhang M, Rao P, Xia D, Sun L, Cai X, Xiao J. Functional reconstruction of mandibular segment defects with individual preformed reconstruction plate and computed tomographic angiography-aided iliac crest flap. J Oral Maxillofac Surg 2019;77:1293–1304.
7. Hanken H, Schablowsky C, Smeets R, et al. Virtual planning of complex head and neck reconstruction results in satisfactory match between real outcomes and virtual models. Clin Oral Investig 2015;19:647–656.
8. Jewer DD, Boyd JB, Manktelow RT, et al. Orofacial and mandibular reconstruction with the iliac crest free flap: A review of 60 cases and a new method of classification. Plast Reconstr Surg 1989;84:391–405, discussion 404–405.
9. Modabber A, Gerressen M, Stiller MB, et al. Computer-assisted mandibular reconstruction with vascularized iliac crest bone graft. Aesthetic Plast Surg 2012;36:653–659.
10. Ayoub N, Ghassemi A, Rana M, et al. Evaluation of computer-assisted mandibular reconstruction with vascularized iliac crest bone graft compared to conventional surgery: A randomized prospective clinical trial. Trials 2014;15:114.
11. Zhang W, Yu Y, Wang Y, et al. Improving the accuracy of mandibular reconstruction with vascularized iliac crest flap: Role of computer-assisted techniques. J Craniomaxillofac Surg 2016;44:1819–1827.
12. Shu DL, Liu XZ, Guo B, Ran W, Liao X, Zhang YY. Accuracy of using computer-aided rapid prototyping templates for mandible reconstruction with an iliac crest graft. World J Surg Oncol 2014;12:190.
13. Li Y, Shao Z, Zhu Y, Liu B, Wu T. Virtual surgical planning for successful second-stage mandibular defect reconstruction using vascularized iliac crest bone flap: A valid and reliable method. Ann Plast Surg 2020;84:183–187.
14. Zheng L, Wu W, Shi Y, Zhang J. Mandibular reconstruction with a deep circumflex iliac artery flap using computer-assisted and intraoral anastomosis techniques. J Oral Maxillofac Surg 2019;77:2567–2572.
15. Lu T, Liu Z, Wu T, Shao Z, Sun Y, Sun Z, Liu B. Application of individualized in-situ moulding guide plate in mandibular reconstruction using a vascularized iliac muscle flap [in Chinese]. Kouqaing Yixue Yanjiu 2019;35:766–771.
16. Zho M, Shao Z, Zhu Y, Liu B, Wu T. Comparison of complicated and simple guiding templates in mandibular reconstruction using vascularized iliac crest flap. Biomed Res Int 2019;2019:7496538.
17. Pohlenz P, Blessmann M, Blake F, Li L, Schmelzle R, Heiland M. Outcome and complications of 540 microvascular free flaps: The Hamburg experience. Clin Oral Investig 2007;11:89–92.
18. Roser SM, Ramachandra S, Blair H, et al. The accuracy of virtual surgical planning in free fibula mandibular reconstruction: Comparison of planned and final results. J Oral Maxillofac Surg 2010;68: 2824–2832.
19. Pfaff MJ, Steinbacher DM. Plastic surgery applications using three-dimensional planning and computer-assisted design and manufacturing. Plast Reconstr Surg 2016;137:603e–616e.
20. Ghassemi A, Ghassemi M, Riediger D, Hilgers RD, Gerressen M. Comparison of donor-site engraftment after harvesting vascularized and nonvascularized iliac bone grafts. J Oral Maxillofac Surg 2009;67:1589–1594.
21. Zheng L, Lv X, Zhang J, Liu S, Zhang J, Zhang Y. Translating computer-aided design and surgical planning into successful mandibular reconstruction using a vascularized iliac-crest flap. J Oral Maxillofac Surg 2018;76:886–893.
22. Lu T, Shao Z, Liu B, Wu T. Recent advance in patient-specific 3D printing templates in mandibular reconstruction. J Mech Behav Biomed Mater 2020;106:103725.
23. Picard-Ami LA Jr, Thomson JG, Kerrigan CL. Critical ischemia times and survival patterns of experimental pig flaps. Plast Reconstr Surg 1990;86:739–745.
24. Ramella V, Franchi A, Bottosso S, Tirelli G, Novati FC, Arnež ZM. Triple-cut computer-aided design-computer-aided modeling: More oncologic safety added to precise mandible modeling. J Oral Maxillofac Surg 2017;75:1567.e1-1567.e6.
25. Shen Y, Sun J, Li J, Li MM, Huang W, Ow A. Special considerations in virtual surgical planning for secondary accurate maxillary reconstruction with vascularised fibula osteomyocutaneous flap. J Plast Reconstr Aesthet Surg 2012;65:893–902.
26. Ganry L, Quilichini J, Bandini CM, Leyder P, Hersant B, Meningaud JP. Three-dimensional surgical modelling with an open-source software protocol: Study of precision and reproducibility in mandibular reconstruction with the fibula free flap. Int J Oral Maxillofac Surg 2017;46:946–957.