Mandibular Reconstruction Using Iliac Flap Based on Occlusion-Driven Workflow Transferred by Digital Surgical Guides

Yi-Fan Kang, DDS, [*] *Meng-Kun Ding, DDS,* [*] *Shi-Yu Qiu, DDS,* [*] *Zhi-Gang Cai, DMD,* [†] *Lei Zhang, MD,* [‡] *and Xiao-Feng Shan, MD* [‡]

Purpose: The current standard for mandibular reconstruction is a contour-based approach using a fibular flap offering good cosmetic results but challenging to reconstruct using dental implants. An iliac flap is more amenable to implant placement and better suited for occlusion-driven reconstruction. We aimed to describe an occlusion-driven workflow that involves the use of digital surgical guides to perform mandibular reconstruction using an iliac flap; we also aimed to compare our results to those we achieved with conventional contour-based reconstruction.

Methods: This was a retrospective cohort study. All patients who underwent mandibular reconstruction with an iliac flap at our university hospital between September 2017 and December 2019 were considered eligible for the study. The inclusion criteria included mandibular defects after tumor ablation and stable preoperative occlusal relationship. The exclusion criteria were as follows: defects involving the condyle and ramus, temporomandibular joint disease, and obvious preoperative nontumor-related facial asymmetry. To evaluate surgical outcomes, patients were assigned to 2 groups based on the implemented surgical workflow: the occlusion-driven and traditional contour-driven groups. The intermaxillary distance, intermaxillary angle, surface deviation, and implantation rates were compared between the 2 groups. The operating time, length, and number of iliac bone segments were recorded. Intergroup differences were investigated using an independent samples *t* test and Fisher exact test.

[*]Resident, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology; National Center of Stomatology, Beijing, China; National Clinical Research Center for Oral Diseases, Beijing, China; National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, China; Beijing Key Laboratory of Digital Stomatology; Research Center of Engineering and Technology for Computerized Dentistry Ministry of Health, Beijing, China; National Medical Products Administration (NMPA) Key Laboratory for Dental Materials, Beijing, China.

†Professor, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China; National Center of Stomatology; National Clinical Research Center for Oral Diseases, Beijing, China; National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, China; Beijing Key Laboratory of Digital Stomatology, Beijing, China; Research Center of Engineering and Technology for Computerized Dentistry Ministry of Health, Beijing, China; National Medical Products Administration (NMPA) Key Laboratory for Dental Materials, Beijing, China.

‡Associate Professor, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology; National Center of Stomatology, Beijing, China; National Clinical Research Center for Oral Diseases, Beijing, China; National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, China; Beijing Key Laboratory of Digital Stomatology, Beijing, China; Research Center of Engineering and Technology for Computerized Dentistry Ministry of Health, Beijing, China; National Medical Products Administration (NMPA) Key Laboratory for Dental Materials, Beijing, China.

Conflict of Interest Disclosures: None of the authors have any relevant financial relationship(s) with a commercial interest.

Address correspondence and reprint requests to Dr Shan: Associate Professor, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, 22# Zhongguancun South Avenue, Haidian District, Beijing, 100081, China; e-mail: bdkqsxf@163.com

Received November 22 2021
Accepted July 12 2022

0278-2391/22/00704-2
https://doi.org/10.1016/j.joms.2022.07.140

Results: Overall, 24 patients were included (13 in the occlusion-driven group and 11 in the contour-driven group). Implantation rate was higher in the occlusion-driven group (61.5%) compared with the contour-driven group (18.2%; $P = .047$). The average acceptable intermaxillary distance was greater in the occlusion-driven group (92.3 ± 27.7%) than in the contour-driven group (47.0 ± 47.6%; $P = .01$). The average intermaxillary angle was 88.2 ± 8.4° in the occlusion-driven group and 76.4 ± 10.3° in the contour-driven group ($P < .01$).

Conclusions: Digital surgical guides can precisely transfer virtual surgical planning to real-world mandibular surgery. An occlusion-driven workflow might provide a better intermaxillary jaw relationship than traditional contour-driven surgical procedures, resulting in improved mastication.

J Oral Maxillofac Surg 80:1858-1865, 2022

Mandibular reconstruction is a mature technique that involves the use of vascularized bone grafts. In recent years, fibular flaps have become the standard treatment. The implementation of digital techniques, such as virtual surgical planning (VSP) and dental implants, has yielded good surgical outcomes in both aesthetic and functional terms.[1-3] The deep circumflex iliac artery bone flap, also known as an iliac flap, was first introduced by Taylor et al.[4] Although Brown has recommended its use for maxillary reconstruction,[5] the iliac flap has not been used as widely as the fibular flap in the mandibular region. However, the iliac flap has some advantages over other bone grafts; specifically, the large amount of bone makes it an ideal choice for dental implant rehabilitation.[6]

Contour-driven mandibular reconstruction with second-phase implantation is the most commonly used and reliable treatment plan in clinical practice. Contour-driven approaches traditionally use the lower margin of the mandible as a reference for reconstruction.[7] In our experience, contour-driven mandibular reconstruction is inconvenient for implant-based denture restoration because of the difference in contour shape between the lower margin of the mandible and mandibular alveolar ridge. In particular, a poor intermaxillary jaw relationship may cause denture rehabilitation failure.[8] The concept of occlusion-driven (OD) maxillofacial reconstruction was introduced in 2003.[9] This approach prioritizes reconstruction of the jaw relationship for better implant placement. In brief, the mandibular alveolus rather than the lower margin was used as a reference for reconstruction. In this study, the prelaminated fibular flap technique was used. Implants were placed at the donor site, and the flap was transferred 4–6 weeks later. Two significant advantages of this technique were the presence of dental implants at the time of free tissue transfer and the ability to deliver immediate dental rehabilitation all during the second surgery. This meant significantly fewer surgical interventions were needed over the entire treatment period. The main disadvantage was the need for at least 2 surgeries under general anesthesia. The OD concept can now be better applied because it can benefit from VSP.

The use of digital techniques such as computer-assisted navigation (CAN) and computer-aided design/manufacturing (CAD/CAM) for mandibular reconstruction has become popular. The most important step is to transfer the VSP to real-world surgery. Several studies have reported that the use of the CAN system for VSP transfer is both stable and efficient.[10-12] However, a limitation of CAN is the increased patient trauma associated with reference frame fixation and intermaxillary fixation (IMF). Moreover, preoperative registration and intraoperative verification increase the overall operation time.[13] A surgical guide is an alternative to CAN, as it not only saves time for navigation registration and verification but also avoids the extra trauma due to reference frame fixation and IMF. Several workflows using surgical guides for fibular flaps have been reported.[14,15] These procedures were efficient and precise for mandibular reconstruction. The purpose of this study was to describe an OD workflow that involves the use of digital surgical guides for iliac flap mandibular reconstruction. We proposed a new method to evaluate jaw relationships for mandibular reconstruction. The specific aims of this study were to measure and compare some variables of interest to prove that the OD workflow with iliac flap might benefit the mandibular reconstruction, especially in implantation rate.

Materials and Methods

STUDY DESIGN/SAMPLE

This retrospective cohort study enrolled patients who underwent mandibular reconstruction using either a traditional contour-driven workflow or an OD workflow at the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology between September 2017 and December 2019. The inclusion criteria were as follows: (1) mandibular defects after tumor ablation, (2) mandibular reconstruction with an iliac flap, and (3) a stable

occlusal relationship before surgery. The exclusion criteria were as follows: (1) defects involving the condyle and ramus, (2) diagnosis of temporomandibular joint disease, and (3) obvious preoperative facial asymmetry not caused by the tumor. This study adhered to the principles of the Declaration of Helsinki in terms of medical protocols and ethics and was approved by the institutional ethics committee (PKUSSIRB - 202055065).

VIRTUAL SURGICAL PLANNING

Preoperative computed tomography (CT) scans (120 kV, 25 mAs, SW = 1.25 mm) of the head, neck, and ilium regions were used for VSP. Tumor resection was simulated using ProPlan CMF 3.0 (Materialise, Belgium). Dental restoration and implants were designed using 3Shape Implant Studio (3Shape, Denmark). According to the position of the dental restoration and implants, the defect was reconstructed based on the unaffected side using a mirroring technique, and the ilium that matched the mirror mandible was selected for reconstruction. The position of the iliac bone segment for implantation was determined according to OD reconstruction. Owing to the height of the iliac bone, the objectives of a contour-driven workflow can be satisfied even when using an OD workflow. After computer simulation, the reconstructed mandibular stereo model was 3-dimensionally (3D) printed. A 2.0-mm reconstruction plate (DePuy Synthes, USA) was prebent according to the stereo model (Fig 1). The relative positions of the reconstruction plate and stereo model were recorded using a 3D scanner (3Shape, Denmark; Fig 2).

The last step was surgical guide design. The surgical guides for mandibular resection and iliac flap harvest had predictive holes corresponding to holes on the reconstruction plate (Fig 3). The surgical guides were designed and manufactured using Geomagic Studio 2013 (3D Systems, USA). The surgical guides were also 3D printed (Fig 4).

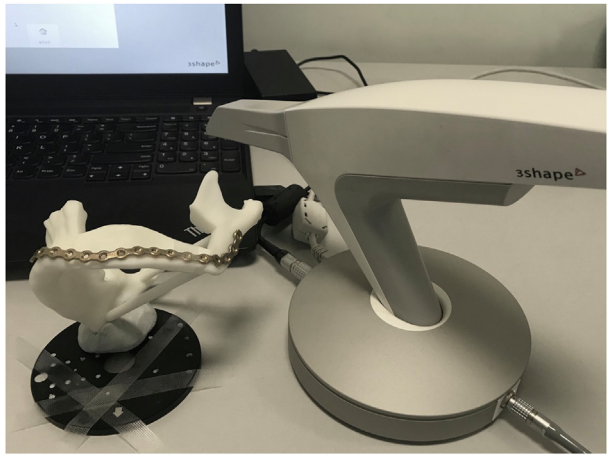

FIGURE 2. The related position between the reconstruction plate and stereo model is recorded using a 3D scanner.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

SURGICAL PROCEDURE

For the OD workflow group, the mandibular guide was fixed using predictive holes after being fully seated. Tumor resection was performed using the mandibular guide. The reconstruction plate was fixed after tumor resection to maintain the relative position of the residual mandible on both sides. The iliac flap was harvested under the iliac guide and fixed to the bone flap according to the predictive holes. After

FIGURE 1. The reconstructed mandibular stereo model is three-dimensionally (3D) printed. A 2.0 reconstruction plate is prebent according to the stereo model.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

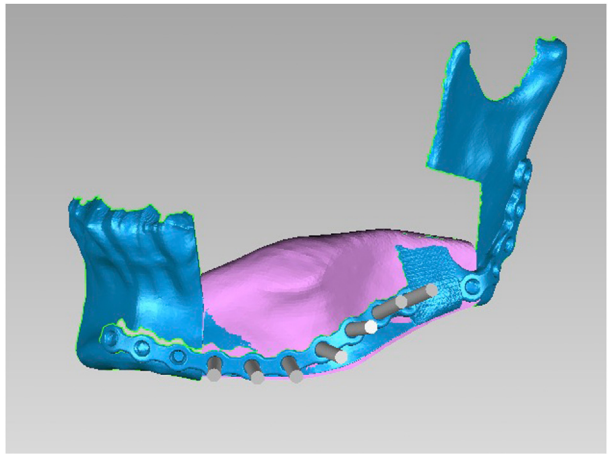

FIGURE 3. The predictive holes are marked with software for both the mandibular resection and iliac flap harvest guides.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

FIGURE 4. Digital surgical guides are both 3D printed.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

shaping, the iliac flap was fixed to the reconstruction plate with the predictive holes (Figs 5-8).

For the contour-driven (CD) workflow group, the mandibular resection and iliac flap harvest depended on CT-based measurements and the surgeon's experience. Iliac bone shaping was also free handed. The basic reconstruction strategy was to ensure that the iliac bone aligned with the inferior border of the mandible. The fixation type, using several mini plates or 1 reconstruction plate, depended on the segment of iliac bone.

VARIABLES/DATA COLLECTION METHODS

The number of patients, sex, age, diagnosis, and Urken classification of mandibular defect were recorded. Operating time, length and number of iliac bone segments, and implantation rates were also recorded for both groups.

CT scans were reconstructed 1 week postoperatively to assess the surface deviation from the VSP mandible model. Three-dimensional comparison was applied to illustrate deviation from the VSP mandible model along a spectrum. The resulting error grade color map represents the surface deviation between the postoperative and VSP mandibular models (Fig 9).

Also, 1 week postoperatively, CT scans were reconstructed using ProPlan CMF software (Materialize, Belgium). Two methods were designed to evaluate the locations of the maxilla and reconstructed mandible. First, the mesiobuccal cusps and mesial angle of the maxillary right central incisor were used

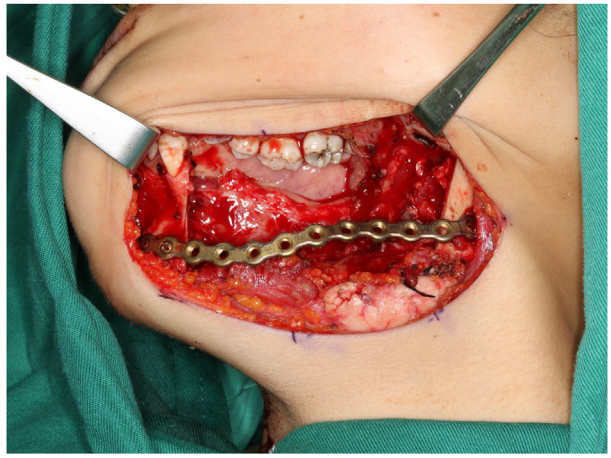

FIGURE 6. The reconstruction plate is fixed after tumor resection to maintain the related position between the residual mandible on both sides.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

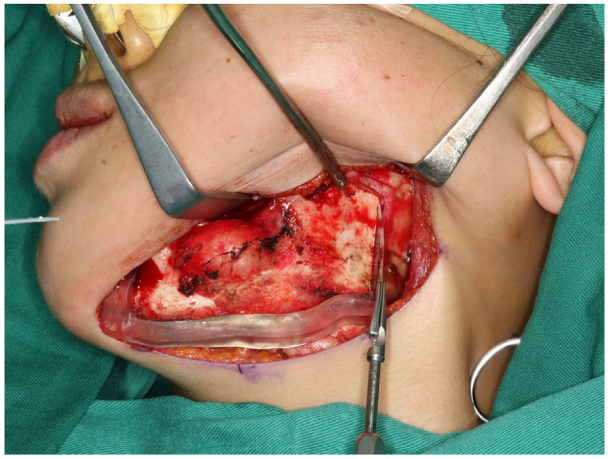

FIGURE 5. Tumor resection is performed using the mandibular guide.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

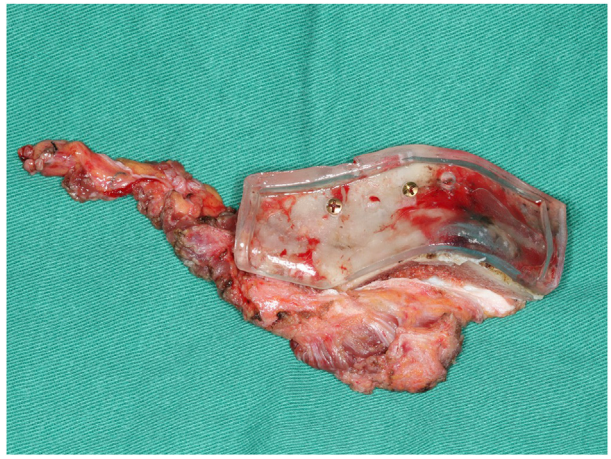

FIGURE 7. The iliac flap is harvested and shaped using a digital surgical guide.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

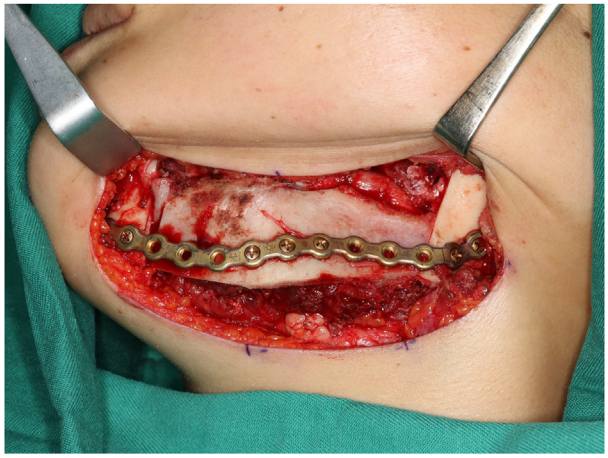

FIGURE 8. The iliac flap is fixed on the reconstruction plate by predictive holes.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

to locate the maxillary occlusion plane. The intermaxillary distance was recorded between the maxillary occlusion plane and the first mandibular molar, canine, and central incisor in the defective region (Fig 10). An intermaxillary distance ≤15 mm was considered acceptable. The acceptable intermaxillary distance for each patient was calculated.

Second, the CT coronal plane was adjusted to the alveolar ridge between the upper first molar and second premolar in the defect region. The midpoints of the upper alveolar and neo-alveolar crests were then connected. The angle between the line and plane of occlusion was recorded (Fig 11). An intermaxillary angle ≥80° was considered acceptable.

DATA ANALYSES

The operation time, iliac length and segment number, implantation rates, rate of acceptable intermaxillary distance, and intermaxillary angle were summarized as mean ± standard deviation or as percentages. Intergroup differences were investigated using an independent-sample *t* test and Fisher exact test in SPSS 26.0 (IBM Corporation, Armonk, NY, USA). A *P* value of <0.05 was considered to indicate statistical significance.

Results

Twenty-four patients were included in this retrospective study. Of these, 13 were treated with the OD workflow and 11 with the CD workflow groups. The characteristics of the 2 groups are presented in Table 1. The average operation time was 357.7 ± 56.6 min in the OD group and 313.6 ± 64.2 min in the CD group. This difference was not significant (*P* = .09). Eight patients in the OD group received dental implants (5 in the first stage and 3 in the second), and 2 patients in the CD group underwent dental implant treatment in the second phase. The implantation rate in the OD group was 61.5%, which was significantly higher than that in the CD group (18.2%; *P* = .047). Eight patients in the OD group had fixed dentures, whereas 1 patient

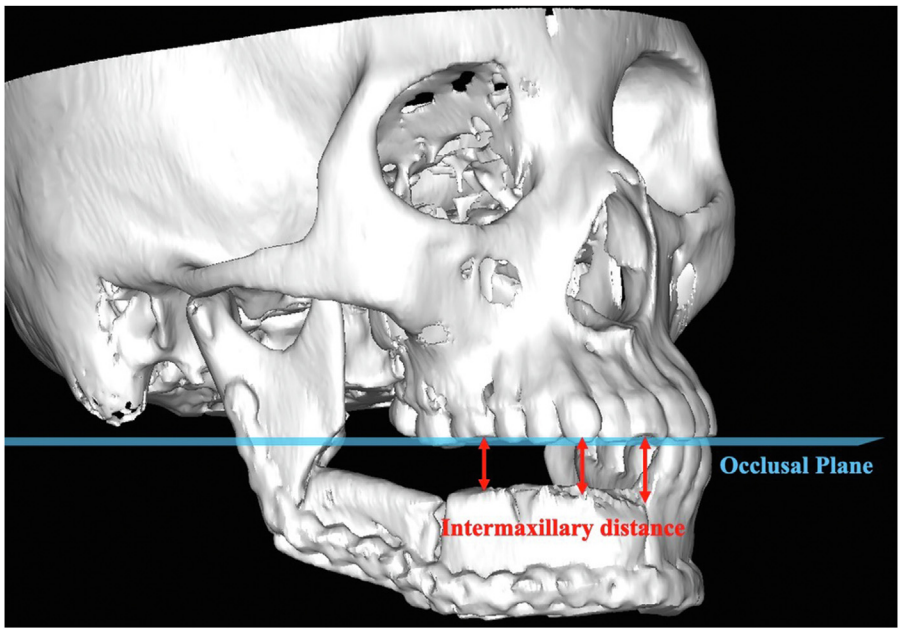

FIGURE 9. "Three-dimensional comparison" is applied to illustrate deviation from the VSP mandible model in a deviation spectrum. The resulting error grade color map represents the surface deviation between the postoperative and VSP mandible models.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

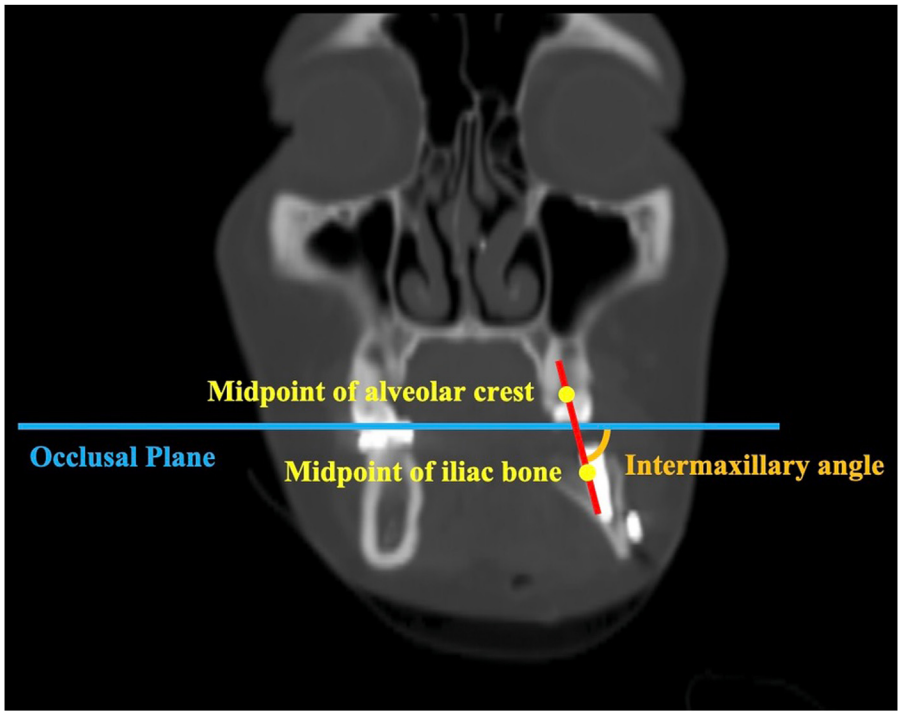

FIGURE 10. The maxillary occlusion plane is located by on both sides of the maxillary first molar's mesiobuccal cusp and maxillary right central incisor's mesial angle. The intermaxillary distance is recorded; it is between the maxillary occlusion plane and the first mandibular molar, canine, and central incisor in the defect region.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

each had fixed and removable dentures in the CD group.

Furthermore, the average rate of acceptable intermaxillary distance in the OD and CD groups was 92.3 ± 27.7% and 47.0 ± 47.6%, respectively; this difference was statistically significant (P = .01). The average intermaxillary angle was 88.2 ± 8.4° in the OD group and 76.4 ± 10.3° in the CD group; this difference was significant (P < .01). These results showed that OD group had a better intermaxillary jaw relationship than CD group. The details of cases with acceptable intermaxillary distance and angle are presented in Tables 2 and 3.

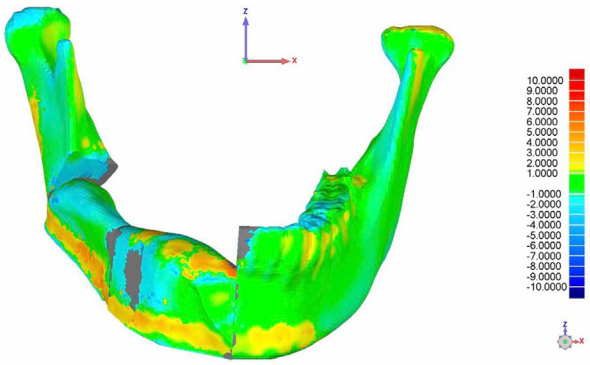

FIGURE 11. The computed tomography coronal plane is adjusted to the alveolar ridge between the upper first molar and second premolar in the defect region. The midpoints of the alveolar crest and iliac bone are connected. The angle between the line and occlusion plane is recorded as the intermaxillary angle.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

Table 1. PATIENT CHARACTERISTICS

	Clinical Details		
Variable	OD Group*	CD Group*	*P* Value
Number of patients	13	11	N/A
Sex			>.05
Male	6	4	
Female	7	7	
Mean age (yr, range)	40.3 (20–58)	39.5 (18–70)	>.05
Disease			>.05
Benign tumor	12	9	
Malignant tumor	1	2	
Urken classification			>.05
BS*	8	8	
B†	5	3	

Abbreviations: CD group, contour-driven workflow group; OD group, occlusion-driven workflow group.

* Body and symphysis.

† Body.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

Table 2. DETAILS OF THE INTERMAXILLARY DISTANCE IN TWO GROUPS

Group	Cases With Acceptable Intermaxillary Distance	Cases With Unacceptable Intermaxillary Distance	*P* Value
OD group	12	1	.02
CD group	5	6	

Abbreviations: CD group, contour-driven workflow group; OD group, occlusion-driven workflow group.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

The average iliac bone length was 6.0 ± 1.3 cm in the OD group and 6.0 ± 1.4 cm in the CD group. The average number of iliac segments was 1.5 ± 0.5 in the OD group and 1.6 ± 0.5 in the CD group. There were no significant differences between the 2 groups in terms of iliac bone length (P = .94) or segment numbers (P = .97). No donor site morbidity was observed in any patient.

Repeatability between the preoperative VSP model and postoperative mandible was 71.1 ± 5.2% within 1 mm, 86.4 ± 2.8% within 2 mm, and 94.2 ± 1.7% within 3 mm. The average maximum deviation was 6.3 ± 0.8 mm. These findings indicate that VSP was precisely transferred to the surgical results using digital surgical guides.

Discussion

Soft tissue–supported rehabilitation cannot prevent resorption of the reconstructed bone; it may actually accelerate the bone resorption process.[16] In other words, dental implant–based rehabilitation may be the best solution for patients undergoing jaw reconstruction. Thus, the implantation rate was one of the most important outcomes to evaluate the results of jaw reconstruction, both for mandible and maxilla. The purpose of this study was to describe an OD workflow for iliac flap mandibular reconstruction, which could improve the implantation rate.

The fibular flap, because of its long vascular pedicle, the wide diameter of peroneal vessels, and several other advantages,[17] has become the first choice for most cases of mandibular reconstruction in recent decades. The disadvantages of the fibular flap became apparent with the development of dental implants; specifically, the lack of bone height made dental implantation less convenient.[18] In our opinion, the iliac flap with adequate bone volume is the first choice for OD mandibular reconstruction. Moreover, dental implant loss was higher in fibular flaps than in iliac flaps,[17] which further made the iliac flap popular. Facial appearance is one of the most important factors influencing social contact. Thus, restoration of a patient's appearance has long been the primary aim of mandibular reconstruction. Rather than using a fibular flap, we combined the advantages of VSP and the iliac flap and placed the bone in a position that is both convenient for implantation and aesthetic for mandibular shape.

The lateral and sagittal positions of the mandible might severely influence dental implant–based rehabilitation, which could result in malocclusion if the surgeon fails to restore the intermaxillary jaw relationship.[19] One of the primary reasons for the relatively low rate of dental implant–based rehabilitation is the poor jaw relationship after reconstruction.[8] We proposed a new method to evaluate jaw relationships for mandibular reconstruction. The standard intermaxillary distance and angle could help surgeons achieve a better jaw relationship in VSP before surgery. This standard is based on Chinese patients, especially the intermaxillary distance; therefore, some adjustments may be required when using this standard in patients of other ethnicities.

The OD concept in previous studies was mandibular reconstruction with one-stage implantation.[7,9] The main reason for one-stage implantation was concerns regarding implant survival after radiotherapy.[20,21] In our study, only 5 patients underwent one-stage implant placement. Because most of them had benign tumors not requiring radiotherapy, second-phase implant placement could have been a reliable choice.

An iliac flap is usually recommended for the reconstruction of a mandibular angle or body defect that is <9 cm long.[17,22] When a defect reconstruction is longer than 14 cm, severe complications can occur.[23,24] The longer the iliac bone harvest, the more pain the patient experiences after surgery.[25] In this study, the average length of the iliac bone was about 6 cm in all cases, and there was no donor site morbidity. Free-hand shaping wastes more surplus bone, especially in a 2-segment iliac flap. In contrast, the digital surgical guide is an advanced approach to

Table 3. DETAILS OF THE INTERMAXILLARY ANGLE IN TWO GROUPS

Group	Cases With Acceptable Intermaxillary Angle	Cases With Unacceptable Intermaxillary Angle	*P* Value
OD group	10	3	.04
CD group	3	8	

Abbreviations: OD group, occlusion-driven workflow group; CD group, contour-driven workflow group.

Kang et al. Mandibular Reconstruction With Digital Surgical Guides. J Oral Maxillofac Surg 2022.

iliac bone harvesting that reduces surplus bone removal and trauma to the donor site. Undoubtedly, patients will benefit from this minimally invasive technique, with lower incidence of complications.

However, this technique has room for improvement. The prebent reconstruction plate that we used can be replaced with a CAD/CAM reconstruction plate in the future. The CAD/CAM reconstruction plate is stronger and more stable because the bending points are mechanically weak.[26] The bending of the reconstruction plate during surgery could be time consuming and difficult and depends on the skill and experience of the surgeon.[26] Although all reconstruction plates in the OD group were prebent, the difference in operating time between the 2 groups was not significant. A limitation of our study was the relatively small sample size.

In summary, the use of digital surgical guides can precisely transfer VSP to real-world surgeries. The OD workflow provided a better jaw relationship than the traditional CD surgical procedure, which is likely a solution for improving masticatory function in patients. Further studies should aim to use CAD/CAM reconstruction plates, which could decrease the additional costs and preparation time and make this technique suitable for routine reconstruction practice.

Acknowledgments

This study was supported by the Capital Health Development Research Project (CFH2020-2-4102).

References

1. Kazaoka Y, Shinohara A, Yokou K, Hasegawa T: Functional reconstruction after a total maxillectomy using a fibula osteocutaneous flap with osseointegrated implants. Plast Reconstr Surg 103:1244–1246, 1999
2. Wijbenga JG, Schepers RH, Werker PMN, Witjes MJH, Dijkstra PU: A systematic review of functional outcome and quality of life following reconstruction of maxillofacial defects using vascularized free fibula flaps and dental rehabilitation reveals poor data quality. J Plast Reconstr Aesthet Surg 69:1024–1036, 2016
3. Sozzi D, Novelli G, Silva R, Connelly ST, Tartaglia GM: Implant rehabilitation in fibula-free flap reconstruction: A retrospective study of cases at 1-18 years following surgery. J Cranio Maxillofac Surg 45:1655–1661, 2017
4. 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 64:745–759, 1979
5. Brown JS, Shaw RJ: Reconstruction of the maxilla and midface: Introducing a new classification. Lancet Oncol 11:1001–1008, 2010
6. Mohlhenrich SC, Kniha K, Elvers D, et al: Intraosseous stability of dental implants in free revascularized fibula and iliac crest bone flaps. J Craniomaxillofac Surg 44:1935–1939, 2016
7. Seikaly H, Idris S, Chuka R, et al: The Alberta reconstructive technique: An occlusion-driven and digitally based jaw reconstruction. Laryngoscope 4(129 Suppl):S1–S14, 2019
8. Zhu H, Zhang L, Cai Z, Shan X: Dental implant rehabilitation after jaw reconstruction assisted by virtual surgical planning. Int J Oral Maxillofac Implants 34:1223–1230, 2019
9. Rohner D, Jaquiery C, Kunz C, Bucher P, Maas H, Hammer B: Maxillofacial reconstruction with prefabricated osseous free flaps: A 3-year experience with 24 patients. Plast Reconstr Surg 112:748–757, 2003
10. Shan XF, Chen HM, Liang J, et al: Surgical navigation-assisted mandibular reconstruction with fibula flaps. Int J Oral Maxillofac Surg 45:448–453, 2016
11. Yu H, Shen SG, Wang X, Zhang L, Zhang S: The indication and application of computer-assisted navigation in oral and maxillofacial surgery-Shanghai's experience based on 104 cases. J Craniomaxillofac Surg 41:770–774, 2013
12. Yu Y, Zhang WB, Liu XJ, Guo CB, Yu GY, Peng X: Three-dimensional accuracy of virtual planning and surgical navigation for mandibular reconstruction with free fibula flap. J Oral Maxillofac Surg 74:1503.e1–1503.e10, 2016
13. Qiu S, Kang Y, Ding M, et al: Mandibular reconstruction with the iliac flap under the guidance of A Series of digital surgical guides. J Craniofac Surg 32:1777–1779, 2021
14. Bao T, He J, Yu C, et al: Utilization of a pre-bent plate-positioning surgical guide system in precise mandibular reconstruction with a free fibula flap. Oral Oncol 75:133–139, 2017
15. Liang Y, Jiang C, Wu L, Wang W, Liu Y, Jian X: Application of combined Osteotomy and reconstruction pre-bent plate position (CORPPP) Technology to assist in the precise reconstruction of segmental mandibular defects. J Oral Maxillofac Surg 75: 2026.e1–2026.e10, 2017
16. Noguchi T, Sarukawa S, Tsuchiya Y, et al: Evaluation of postoperative changes in vascularized iliac bone grafts used for mandibular reconstruction. Int J Oral Maxillofac Surg 47:990–997, 2018
17. Lonie S, Herle P, Paddle A, Pradhan N, Birch T, Shayan R: Mandibular reconstruction: meta-analysis of iliac- versus fibula-free flaps. Anz J Surg 86:337–342, 2016
18. Chang YM, Tsai CY, Wei FC: One-stage, double-barrel fibula osteoseptocutaneous flap and immediate dental implants for functional and aesthetic reconstruction of segmental mandibular defects. Plast Reconstr Surg 122:143–145, 2008
19. Schliephake H, Schmelzeisen R, Husstedt H, Schmidt-Wondera LU: Comparison of the late results of mandibular reconstruction using nonvascularized or vascularized. grafts and dental implants. J Oral Maxillofac Surg 57:944–950, 1999
20. Zhang L, Ding Q, Liu C, Sun Y, Xie Q, Zhou Y: Survival, function, and complications of oral implants placed in bone flaps in jaw rehabilitation: A systematic review. Int J Prosthodont 29:115–125, 2016
21. Pellegrino G, Tarsitano A, Ferri A, Corinaldesi G, Bianchi A, Marchetti C: Long-term results of osseointegrated implant-based dental rehabilitation in oncology patients reconstructed with a fibula free flap. Clin Implant Dent Relat Res 20:852–859, 2018
22. Taylor GI, Miller GD, Ham FJ: The free vascularized bone graft. A clinical extension of microvascular techniques. Plast Reconstr Surg 55:533–544, 1975
23. Urken ML: Composite free flaps in oromandibular reconstruction. Review of the literature. Arch Otolaryngol Head Neck Surg 117:724–732, 1991
24. Cuellar CN, Caicoya SJO, Sanz JJA, Cuellar IN, Muela CM, Vila CN: Mandibular reconstruction with iliac crest free flap, Nasolabial flap, and osseointegrated implants. J Oral Maxillofac Surg 72:1226.e1–1226.e15, 2014
25. Liu Q, Shao Z, Shang Z: Mandibular reconstruction using the deep circumflex iliac artery free flap: Effect of the length of bone harvested on donor site morbidity. Br J Oral Maxillofac Surg 57:778–781, 2019
26. Rana M, Chin SJ, Muecke T, et al: Increasing the accuracy of mandibular reconstruction with free fibula flaps using functionalized selective laser-melted patient-specific implants: A retrospective multicenter analysis. J Cranio Maxillofac Surg 45: 1212–1219, 2017