Original Article

Virtual surgical planning is a useful tool in the surgical management of mandibular condylar fractures

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Abstract

Purpose: The aim of this study is to evaluate the application value of virtual surgical planning in the management of mandibular condylar fractures and to provide a reliable reference.

Methods: This was a prospective randomized controlled study and recruited 50 patients requiring surgical treatment for their mandibular condylar fractures. The inclusion criteria were patients (1) diagnosed with a condylar fracture by two clinically experienced doctors and required surgical treatment; (2) have given consent for the surgical treatment; and (3) had no contraindications to the surgery. Patients were excluded from this study if: (1) they were diagnosed with a non-dislocated or only slightly dislocated condylar fracture; (2) the comminuted condylar fracture was too severe to be treated with internal reduction and fixation; or (3) patients could not complete follow-up for 3 months. There were 33 male and 17 female patients with 33 unilateral condylar fractures and 17 bilateral condylar fractures included. The 50 patients were randomly (random number) divided into control group (25 patients with 35 sides of condylar fractures) and experimental group (25 patients with 32 sides of condylar fractures). Virtual surgical planning was used in the experimental group, but only clinical experience was used in the control group. The patients were followed up for 1, 3, 6 and 12 months after operation. Variables including the rate of perfect reduction by radiological analysis, the average distance of deviation between preoperative and postoperative CT measurements using Geomagic software and postoperative clinical examinations (e.g., mouth opening, occlusion) were investigated for outcome measurement. SPSS 19 was adopted for data analysis.

Results: The average operation time was 180.60 min in the experimental group and 223.2 min in the control group. One week postoperatively, CT images showed that the anatomic reduction rate was 90.63% (29/32) in the experimental group and 68.57% (24/35) in the control group, revealing significant difference ($X^2 = 4.919, p = 0.027$). Geomagic comparative analysis revealed that the average distance of deviation was also much smaller in the experimental group than that in the control group (0.639 mm vs. 0.995 mm; $t = 3.824, p < 0.001$).

Conclusion: These findings suggest that virtual surgical planning can assist surgeons in surgical procedures, reduce operative time, and improve the anatomic reduction rate & accuracy, and thus of value in the diagnosis and treatment of condylar fractures.

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Introduction

The mandible occupies a prominent position on the face, and the condyle, with its slender structure, is one of the most common sites of facial fractures. Condylar fracture, compared with fractures of other parts of the mandible, is more difficult to handle with. Although currently surgical treatment is the preferred choice among surgeons for the management of condylar base and neck fractures,1,2 the technique-demanding is much higher than that for other mandibular fractures. To improve the surgical treatment of condylar fractures, many studies targeting at the surgical approach, accurate diagnosis, accurate reduction, stable fixation, functional rehabilitation training and other aspects have been conducted.3,4 However, despite these research, many surgeons, especially those
with insufficient surgical experience, still struggle to establish a
definite diagnosis and treatment plan during the management of
mandibular condylar fractures.

In recent years, the development of digital surgery has provided
a new way to solve these problems. Surgical procedures are no
longer only dependent on the subjective judgment of the surgeon
whereas digital technology in the surgical field is used to establish a
precise medical treatment.11–12 Virtual surgical planning (VSP) is one
such digital technology innovation. The clinical use of VSP in plastic
surgery, thoracic surgery, and oral and maxillofacial procedures has
been discussed and published in the literature.7–10 Yang et al.11
used a three-dimensional (3D) simulation system to assist in the
surgical treatment of condylar fractures. The results show that VSP
can assist in making an accurate diagnosis and shorten the opera-
tion time. Likewise, Iwai12 indicated that preoperative simulation
can assist in selecting the method of fixation and the length of
screw to fix the fractured condylar fragments. Additionally, Boffano
et al.13 reported that VSP helps surgeons to increase the intra-
operative efficiency of procedures. However, there is still little
literature in this field and all the previous studies we retrieved are
case reports or summaries of clinical experience.14 To date, there
have been no reliable randomized controlled clinical studies. Some
scholars think that VSP is of little value for condylar fractures, and
VSP is still not used in most cases.

Therefore, we designed a randomized controlled study to eval-
uate the application value of VSP in mandibular condylar fractures,
with the aim of providing a reliable reference for its clinical use in
the diagnosis and treatment of condylar fractures.

Methods

This study was a prospective, randomized non-blinded
controlled clinical trial and has been approved by the Institu-
tional Review Board of West China Hospital of Stomatolgy at
Sichuan University (2020YJ0278). The guidelines of the Helsinki
Declaration were followed. Consent was obtained from the patient
for the inclusion of their photographs in this article.

All patients met the following inclusion criteria: (1) they were
diagnosed with a condylar fracture by two clinically experienced
doctors and required surgical treatment; (2) they gave consent for
the surgical treatment; and (3) they had no contraindications to the
surgical approach was determined in accordance with the classi-
fication of condylar fractures used by Neff et al.15 in their 2014
publication. For condylar head fractures, a supratemporalis
approach with preauricular incision16 was used; and for neck and
subcondylar fractures, a minor parotid anterior approach,17 which is
a kind of transmasseteric anteroparotid approach, was used. Once
the condyle and the fractured segment were exposed, the

| Study variables | Experimental group (n = 25) | Control group (n = 25) | Statistical values | p value |
|-----------------|---------------------------|----------------------|--------------------|--------|
| Mean age (years) | 37.72                     | 32.68                | t = 1.081           | 0.285  |
| Male/Female     | 18/7                      | 16/9                 | X² = 0.368          | 0.544  |
| Fracture side, n (%) |                   |                      | X² = 0.802          | 0.370  |
| Unilateral      | 18 (72)                   | 15 (60)              |                    |        |
| Bilateral       | 7 (28)                    | 10 (40)              |                    |        |
| Accompanied injuries, n (%) |          |                      |                    |        |
| Other fractures of the mandible | 12 (48) | 13 (52)              | X² = 0.08           | 0.777  |
| Fractures in other parts of the maxillofacial region | 8 (32) | 10 (40)              | X² = 0.347          | 0.556  |
| Other body fractures (limb fractures, rib fractures, cervical vertebra fractures, etc.) | 5 (20) | 7 (28)               | X² = 0.439          | 0.508  |
fractured condylar portion was reduced to a more favorable anatomic position. In the experimental group, the fracture was reduced and fixed in accordance with the presurgical VSP, whereas in the control group the treatment was performed only on the basis of the surgeon’s experience. Other facial fractures that required surgical treatment were also reduced and fixed.

All the patients were treated with intermaxillary traction for 1 week. A postoperative CT scan was taken 1 week after the surgery. Follow-up visits took place at 1, 3, 6 and 12 months after surgery. Clinical follow-up was provided by two surgeons from the surgical team. Radiological analysis was performed by two doctors who were not in the surgical team. The judgement criteria were based on the method of Ellis et al. The fracture reduction results were classified as “perfect”, “satisfactory” and “poor” reduction. A “perfect” was one in which the condylar process was anatomically aligned along all external osseous contours without gaps or irregularities. A “satisfactory” reduction was one in which there may have been a gap (<2 mm) between the fragments, or a slight misalignment of external osseous contour. However, the condylar process was still in good alignment with the head located in the center of the mandibular fossa. A “poor” reduction was one in which there was lack of alignment of the external contour, a large gap, or in which the head was not located in the center of the mandibular fossa. The average distance of deviation between the preoperative surgical plan and the postoperative imaging data was analyzed using Geomagic Studio software.

The independent-samples t-test and χ² test (Fisher’s exact probability method) were used for statistical analysis. All statistical analyses were calculated using SPSS 21.0 for Windows software (IBM Corp, USA). A value of p < 0.05 was considered to indicate statistical significance.

Results

All the 50 patients (67 sides) completed the study, and all of the surgical procedures were finished successfully. The average surgical duration was 180.60 min in the experimental group and 223.2 min in the control group.

As shown in Table 2, the study variables of postoperative radiological analysis and Geomagic comparative analysis showed statistically significant differences. Postoperative CT examination showed that 29/32 sides in the experimental group (90.63%) achieved anatomic reduction compared with only 24/35 sides in the control group (68.57%) (χ² = 4.919, p = 0.027), indicating that preoperative VSP can assist surgeons in achieving more precise reduction of the fractured segment. Comparative Geomagic analysis showed that the average distance of deviation in the experimental group was 0.639 mm, and that of the control group was 0.995 mm. The statistical analysis showed that the fractured bone was in a more desirable anatomic position in the experimental group than in the control group (t = 3.824, p < 0.01).

Postoperatively, all the patients healed uneventfully without any complications such as infections, facial nerve injuries, or salivary fistulae. As shown in Table 3, the 3-month follow-up showed that the range of mouth opening, occlusion, and temporomandibular joint function in the experimental group were slightly better than those in the control group. However, there were no significant differences between the two groups.

Discussion

With abundant evidence of successful case reports and studies supporting the advantages and better prognosis of mandibular

Fig. 1. The protocol for the experimental group. (A) Preoperative CT coronal view; (B) Preoperative digital model constructed with Mimics software; (C) Virtual surgical planning showing repositioning of the fractured portion and preoperative design of the location and direction of screw insertion; (D) Postoperative CT coronal view; (E) Postoperative digital model constructed with Mimics software; (F) Measurement of the average distance of deviation using Geomagic software.
condylar fractures by surgical management, it has become one common choice among many surgeons.2–22 However, due to the location of the condyle, the difficulty of stabilizing a weak fractured portion of the condyle, and intraoperative and postoperative complications, surgical management still presents technical-demanding.23 Therefore, many surgeons, especially those with limited surgical experience, regard surgical treatment of condylar fractures as challenging.

VSP, a recent adjunct to the surgical treatment of maxillofacial fractures, has been reported to intraoperatively assist to achieve superior results for reduction and fixation.21–25 To date, however, there have been no randomized controlled clinical studies of its application in the surgical management of mandibular condylar fractures. We therefore undertook this study to provide a clinical reference and further understanding of the application value of VSP. The results of this study showed that perfect reduction was superior in the experimental group than in the control group. Additionally, the average distance of deviation from the preoperative VSP was shorter in the experimental group than in the control group according to Geomagic analysis. These results indicate that the probability of obtaining a more precise perfect reduction was higher in the experimental group than in the control group. Perfect reduction promotes early healing, reduces bone remodeling, and thus significantly enhances the early recovery of temporomandibular joint function. The above results are consistent with the research conclusion by Dr. Pavlychuk et al.26 They treated 14 patients with 16 condylar head fractures (CHFs) by open reduction and internal fixation with the use of CAD/CAM technology. The results showed that the application of the CAD/CAM technologies for condylar head fractures helps to improve the accuracy and quality of fragments reduction with minimal risks of intraoperative complications.

The findings of this study have demonstrated the following application values of VSP: (1) allows prediction of the postoperative outcome, mainly for condylar head fractures; (2) assists in the perfect reduction of the fractured portion, and predetermination of the screw length in cases of condylar head fractures; (3) provides accurate digital evaluation after the successful surgical treatment. These attributes are of great significance not only in improving the surgical outcomes of condylar fractures, but also in reducing the likelihood of medical disputes.

In conclusion, VSP has major application value in the diagnosis and treatment of condylar fractures, especially for condylar head fractures. It’s well worth using in clinical practice.

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**Ethical statement**

This study was approved by the Institutional Review Board of West China Hospital of Stomatology at Sichuan University (Approval No. WCHSIRB-D-2017-216).

**Declaration of competing interest**

The authors declared no conflicts of interest.

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**Author contributions**

Lei Liu and Shubhechha Shakya designed experiments. Shubhechha Shakya, Kai-De Li and Dou Huang conducted the experiments. Shubhechha Shakya, Zuo-Qiang Liu and Xiao Zhang analyzed data. Shubhechha Shakya wrote original draft. Lei Liu conducted writing revisions and editing. Lei Liu supervised the work. All authors approved the final version of the paper.

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