RESEARCH ARTICLE

Outcomes of V-cut Osteotomy on the First Metatarsal Head Combined with Fixation in Mortise-shaped Bone Groove-Plasty and Akin Osteotomy on the First Toe for Hallux Valgus Correction

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Objective: Hallux valgus (HV) is a common foot deformity, and recurrence is one of the most serious complications after HV correction. As a result, the surgical technique with a lower recurrence rate is a dream. The purpose of the article should be to observe the correction effect of hallux valgus using a novel “V-cut” osteotomy on the first metatarsal head combined with fixation in mortise-shaped bone groove-plasty technique.

Methods: Twenty-three consecutive patients (40 feet) with HV were included from March 2019 to May 2020, who were all treated using single screw fixation with V-cut osteotomy on the first metatarsal head combined with mortise-shaped metatarsal bone groove-plasty and Akin osteotomy on the first toe for hallux valgus correction. With a mean follow-up time of 21.7 months, the visual analogue scale (VAS) score and American Orthopedic Foot and Ankle Society (AOFAS) forefoot score and the changes of the hallux valgus angle (HVA), intermetatarsal angle (IMA) and distal metatarsal articular angle (DMAA) were evaluated during the clinical follow-up. The paired t test was used for analytical statistics.

Results: The VAS score improved from 6.78 ± 1.74 to 1.87 ± 1.45 and the AOFAS score improved from 53.9 ± 12.3 to 94.7 ± 6.8 in the latest follow-up postoperatively (P < 0.01). Besides, the HVA improved from 30.0 ± 6.1° to 5.7 ± 2.8° (P < 0.01); the IMA changed from 13.1 ± 2.8° into 3.3 ± 1.6° (P < 0.01); and the DMAA ameliorated from 27.0 ± 8.4° to 5.9 ± 3.5° (P < 0.01). Only five toes had slight numbness and stiffness in early postoperative period, and these symptoms disappeared completely at 6 months after the surgery. Only one foot was corrected to excess. One screw stem protruding beneath the skin happened, which needed secondary screw removal under local anesthesia.

Conclusions: Single screw fixation with V-cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped metatarsal bone groove-plasty and Akin osteotomy on the first toe is an effective way with low recurrence rate for HV correction.

Key words: Akin Osteotomy; Hallux Valgus; Mortise-shaped bone groove-plasty; V-cut Osteotomy

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Introduction

Hallux valgus (HV), which includes medial deviation of the first metatarsal and lateral deviation of the sesamoids, is a common forefoot deformity, especially in women. This is manifested as progressive external deviation and pronation of the proximal phalanx of the hallux combined with adduction, pronation, and elevation of the first metatarsal leading to bunions.

Among them, foot pain and difficulty in wearing shoes, currently, the diagnostic criteria of HV contain hallux valgus angle (HVA) > 15° and intermetatarsal angle (IMA) > 9°. The severity of HV can be classified according to the above two angles. Besides, distal metatarsal articular angle (DMAA) is usually increased in adults and adolescents diagnosed with HV.

Whether to perform an operation or not, depends on the clinical symptoms. A surgery is necessary when the life quality of patients is reduced, which is caused by a series of reasons, such as foot pain, difficulties in wearing shoes, dysfunction of walking and running abilities. Nowadays, with the deepening of learning HV, there are more than 150 operative approaches invented by surgeons, comprising bunionectomy, metatarsals, phalangeal osteotomy, resection, interposition arthroplasty, and metatarsophalangeal joint arthrodesis. Among them, osteotomies are the most important orthopedic surgeries, such as Chevron osteotomy, Scarf osteotomy, Michelle osteotomy and Akin osteotomy. Although numerous surgical techniques are used, none could completely avoid recurrence after correction, which is the most common problem after HV correction, and many factors may lead to the problem, but there is no consensus. What is more, many fixation instruments were described in the previous literature, such as screws, Herbert screws, K-wires, suture wire, staples, plate or suture. However, no recurrence cannot be guaranteed after operation, while it is considered that fixation loosening is one of the most important complications postoperatively. Moreover, increasing the amount of internal fixation is closely related to the medical cost. Our study was focusing on a new operative approach, namely V-Cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped metatarsal bone groove-plasty on the first metatarsal, which was developed from woodworking mortise and tenon technology to treat HV in order to improve initial fixation stability, and decrease the recurrence possibility. Therefore, the aims of the study were: (i) to investigate the clinical therapeutic effects of the V-Cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped metatarsal bone groove-plasty on correcting HV; and (ii) to evaluate the recurrence rate of the surgical technique.

Methods

Patients

From March 2019 to May 2020, 23 patients (40 feet) were diagnosed as HV definitely, and underwent the corrective operation by means of our new technique. The inclusion criteria included: (i) mild or moderate HV; (ii) age over 18; and (iii) treated by V-Cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped metatarsal bone groove-plasty. The exclusion criteria included: (i) osteoporosis; (ii) rheumatoid arthritis; (iii) blood coagulation dysfunction; (iv) abnormal function of important organs; and (v) stiffness of the metatarsophalangeal joint. All the procedures are performed using the following unified operative technique by a same surgeon. This retrospective study was approved by the Ethics Committee of Shanghai Ninth People’s Hospital, Shanghai Jiaotong University School of Medicine, certificate number SH9H-2020-T44-2. Informed consent was not needed due to the retrospective nature of the study. All methods were carried out in accordance with relevant guidelines and regulations.

Operative Procedures

The general surgical process was shown in Fig. 1, and the detailed process was following:

Preoperative Preparation

Patients were informed of the procedures of the surgery.

Anesthesia and Position

With the patient supine, general anesthesia, surgeons sat facing the median aspect of the foot, in order to perform the surgery better.

Approach and Exposure

A 3-4cm incision was made on the medial side of the first metatarsal, the spade knife or hook knife of our self-developed Soft Tissue Release Kit (Fig. 2A, B) was extended from the incision to the opposite side to release the sesamoid suspensory ligament and adductor hallucis near the metatarsophalangeal joint (Fig. 3, video 1), and subperiosteal dissection around the osteotomy area of the first metatarsal bone was performed with the detach器 (Fig. 2C). Attention should be paid to preserving soft tissue attached to the first metatarsal head in order to avoid nonunion of metatarsal bone. Then, one 1.0 or 0.8 mm Kirschnner wire (K-wire) labeled the V-cut apex was drilled at a 2–3 mm approach from the inner center of the first metatarsal head. Then the following V-cut with two asymmetrical arms was performed (Fig. 4), in which the upper short arm was at an angle of approximate 75° to the ground and the lower long arm approximately paralleled to the ground.

After a V-cut with short upper arm and long lower arm was performed at the distal site of the above-mentioned osteotomy site (Fig. 5A, C), a 2nd cut for a mortise-shaped bone groove was made at the distal and medial site of the first metatarsal head (Fig. 5B, C). The distal metatarsal bone was pushed outward about 70%–90% of the whole metatarsal head according to the tension generated by lateral shift of
the metatarsal head (enough for correcting HV), making the lateral angle of the osteotomy end of metatarsal trunk embedded into the bone groove (Fig. 5D,E). The metatarsal head was rotated and DMAA was corrected at the same time (Fig. 6). A 22–28 mm double-head compressive screw (ITS GmbH, Straelen, Germany) with the diameter of 2.5 mm was used to fix the shaft chips in a long oblique axis from medial-proximal-upside to lateral-distal-downside of the metatarsal head and the protruding bone was cut before trimming the medial osteotomy surface (Fig. 5F), which would be implanted into medullary space of proximal metatarsal shaft to fix the lower arm of osteotomy site.

**Fixation and Suture**

Then the Akin osteotomy was performed at the median site of the first phalanx, correcting distal articular set angle (DASA), and the bone was fixed with 20–28 mm double-thread screw.

The joint capsule was sutured at the medial site, but not tightened too much which may limit the movement of first metatarsophalangeal joint. This is one of the important steps for the satisfaction of the patients. After attaining satisfactory correction by the loading test, the capsule was cleaned with normal saline and sutured layer by layer. Toes were split and bandaged separately.
Postoperative Management
All our patients were permitted to walk wearing off-loading forefoot shoes 1–2 days after the operations. And they could walk with a completely weight bearing 6 weeks after the operations. After 10 weeks, patients could participate in sports.

Assessment
The visual analogue scale (VAS) score and American Orthopedic Foot & Ankle Society (AOFAS) forefoot score were used for the clinical measurements.6 In addition, the radiographic assessment was completed by calculating HVA, IMA and DMAA in

Fig. 4 One K-wire was fixed 3 mm approach from the inner center of the first metatarsal head, as the vertex of V-cut osteotomy.

Fig. 5 (A) Vertical view of the first osteotomy (V-cut osteotomy). (B) Vertical view of the second osteotomy (mortise-shaped bone groove). (C) Side view of the second osteotomy (mortise-shaped bone groove). (D) Outward push of distal metatarsal bone. (E) Lateral angle of the proximal metatarsal bone embedded into the bone groove. (F) Fixation with a double-head compressive screw.

Fig. 6 The distal metatarsal bone was pushed outward. IMA and DMAA were corrected.
Fig. 7 Appearance and corresponding X-rays of the feet preoperatively and postoperatively of a 26-year-old woman (A, B) and a 39-year-old woman (C, D).
weightbearing anteroposterior radiographs. All the measurements were performed twice by the same researcher who did not participate in the surgeries and was not involved in the management of the patients, 2–4 weeks apart. The means and standard deviations were used for statistical analysis.

### Statistical Analysis

The paired *t* test was used for analytical statistics. Intra-class correlation coefficient and kappa identity test were used for consistency test for inter-observer comparisons. Quantitative variables were expressed as means ± standard deviation and qualitative variables were expressed as figures. Differences with *P* < 0.01 (95% confidence interval) were considered significantly different.

### Results

#### Baseline Characteristics of Patients

As for patients’ characterizations, 23 patients (40 feet) in total, included 21 women and two men, with the mean age of 39.3 years (22–67), which was identical to high-risk people and age of HV. Among the 23 patients, four patients (four feet) combined claw toes, two patients (three feet) combined little toe varus deformity, one patient (two feet) combined flatfoot, one patient (one foot) combined soft tissue foreign body granuloma and lipoma, one patient (one foot) combined osteochondroma of the hallux sesamoid. Claw toes and little toe varus deformity were treated with Weil osteotomy, and soft tissue foreign body granuloma and lipoma and osteochondroma were resected completely during the operation. In general, the surgeries lasted for about 1 h, and the blood loss was less than 10 mL as a result of tourniquet.

#### Follow-up Outcomes

With the mean follow-up time of 21.7 months, the VAS scores improved from 6.78 ± 1.74 to 1.87 ± 1.45 after the surgeries and the AOFAS scores improved from 53.9 ± 12.3 preoperatively to 94.7 ± 6.8 postoperatively, which was significantly different (*P* < 0.01). All the patients were satisfied with the outcomes of the surgeries (Fig. 7). Notably, the metatarsal shafts were not shortened obviously.

In addition, the radiographic assessment showed that the HVA, the major measurement of HV, improved from 30.0 ± 6.1 to 5.7 ± 2.8° (*P* < 0.01), the IMA changed from 13.1 ± 2.8° into 3.3 ± 1.6° (*P* < 0.01), and the DMAA ameliorated from 27.0 ± 8.4° to 5.9 ± 3.5° (*P* < 0.01) (Fig. 8, Table 1). The consistency test showed the assessments of HV displayed a satisfied consistency with an intra-class correlation coefficient of 0.87 and kappa value of 0.82.

#### Complications

All the patients had excellent correction after the operation, and no foot was considered as a recurrence after correction in the clinical observation, as well as the patients self-evaluation. Three big toes had a little numbness, two first metatarsophalangeal joints had slight stiffness post operation and these symptoms disappeared completely at 6 months after the surgery. One foot had the screw extruding subcutaneously, which needed a second mini-operation to take out, and another had slight hallux varus, which did not trouble the patient at all and did not need any retreatment. None of any other complications in these patients came out in the follow-up period.

### Discussion

#### Summary of This Study

In this study, we invented a new surgical technique (V-Cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped bone groove-plasty for HV correction. The new surgical technique showed good corrective effects for HV, namely evident improvement of HVA, IMA, DMAA, AOFAS and VAS scores. Notably, no patients reported recurrence of HV,
which was the most vital advantage of our surgical technique.

**Comparisons of Other Approaches and Our Surgical Technique**

Osteotomy is the major operative approach for hallux valgus, which has developed into a variety of ways. The classical operative approaches include Chevron osteotomy, Michelle osteotomy, Scarf osteotomy and a series of modified osteotomies for the first metatarsal bone. Also, Akin osteotomy is one of the most classical operative approaches for the first phalanx correction.

In spite of numerous operative approaches, complications following HV surgery have been reported to be up to 50%, among which the most common complication is recurrence of HV.\(^7\) A study reported that recurrence rates after proximal metatarsal osteotomy ranged from 4% to 25%.\(^8\) In terms of the risk factors of recurrence, although the mechanism of recurrence after HV surgical correction is not totally known, it is accepted that incomplete correction of HVA, IMA and DMAA is an important one.\(^9,10\) In addition, the excessive length of first ray,\(^11\) anatomical defect (skeletal immaturity, hypermobility and congruent joint), systemic factors (rheumatoid arthritis, gout, hyper laxity, neuromuscular condition and cerebrovascular accident), individual lifestyles (such as smoking and continued wearing of high heels) are also important factors of HV recurrence. As for the surgical factors, incomplete reduction of the medial sesamoids\(^12\) and the incomplete correction of the first ray are important factors causing the recurrence. From our perspective, maintaining the alignment of the first metatarsal is of great importance. Taking Chevron osteotomy as an example, it has been reported that recurrent asymptomatic hallux valgus appears in both proximal chevron osteotomy (6.5%) and distal chevron osteotomy (2.2%).\(^13\)

Although numerous operative approaches have been proposed aiming at treating HV recurrence, including Scarf osteotomy,\(^14\) modified subcapital metatarsal osteotomy,\(^15\) and lengthening Scarf osteotomy.\(^16\) The recurrence of HV increases the healthy and economic burden of patients, leading to the double hit to patients. Herein, seeking a specific operative approach with lower recurrence rate seems more and more necessary.

Since that incomplete correction of HVA and unstable fixation contributed to the recurrence of HV, here we performed a new modified osteotomy for hallux valgus combining V-cut with mortise-shaped metatarsal bone groove-plasty and carried out an initial clinical observation, which showed encouraging results. Apparently, this orthopedic effect was satisfactory. In our study, HVA decreased from 30.0 ± 6.1 to 5.7 ± 2.8, IMA decreased from 13.1 ± 2.8 to 3.3 ± 1.6, and DMAA changed from 27.0 ± 8.4 into 5.9 ± 3.5. The corrections of HV-related angles were similar to others' surgeries, which meant that the new technique could achieve good orthopedic effects.\(^17,18\) Functionally, the AOFAS score, with the surgical technique, improved from 53.9 ± 12.3 preoperatively to 94.7 ± 6.8 postoperatively, significantly changed, and the VAS scores improved from 6.78 ± 1.74 to 1.87 ± 1.45. The functional improvements of our surgical technique were basically consistent with other modified Chevron osteotomies.\(^19,20\) Encouragingly, none of the 23 patients (40 feet) had HV recurrence during the follow-up time. This was the highlight of the modified osteotomy. When it comes to the probable reason why our surgery can lower the recurrence rate of HV, the 70%–90% outward push of the metatarsal head is allowed which guarantees the enough correction of HVA and helps maintain the alignment of the first ray. In addition, the mortise-shaped metatarsal bone groove-plasty is beneficial for the lateral angle of the osteotomy end of metatarsal trunk stuck into the bone groove, making the fixation more stable after the drill of the screw. The introduction and combination of V-cut and mortise-shaped metatarsal bone groove-plasty in our technique not only avoids the reduction of pushed bones but also causes stabler fixation with the tightening of the screw. Meanwhile, another advance of our technique is to determine the length of mortise-shaped bone groove-plasty according to the tension of the first tarsometatarsal joint, which may influence the corrective efficiency, fully demonstrating the concept of personalized treatment. Stable fixation and enough shift of bone chips make sure the biomechanical alignment of the first ray. Compared with traditional osteotomies of HV, our modified osteotomy is effective and easy to promote, which is beneficial to lowering the recurrence rate of HV, and even avoids it.

**Advantages of the Modified Surgical Approach**

This procedure has these advantages: (i) the introduction of mortise-shaped bone groove increases the stability, which benefits the one-screw fixation, is helpful for control in the direction of the metatarsal head, contributes to early weight-bearing, and prevents the outward pushed metatarsal head from restoration when the screw is screwed in, ensuring the orthopedic effect; (ii) adequate outward pushing of distal metatarsal head obviously decreases the IMA and avoids the recurrence of HV, and helps the first ray be maintained along the tension of the lateral soft tissue of the first ray, avoiding the recurrence; (iii) the modified surgery with one-screw fixation is simple, spending shorter time so as to improve operative safety, and lowers the cost of the therapy, decreasing the numbers of implants and reducing the risk of infection.

**Strengths and Limitations**

In this study, we performed an initial investigation on the V-cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped bone groove-plasty in correcting HV. The effective correction was proved by initial research with small sample size, which was a study method to save time and money. However, there are several limitations in our study. The sample size is not large enough to show more clinical circumstances. It is necessary to expand clinical observation size and the follow-up time. As a result, a prospective clinical trial with larger sample size and longer
follow-up time is urged to prove the effects of our modified osteotomy furtherly.

**Conclusion**

The new surgical technique, V-Cut osteotomy on the first metatarsal head combined with fixation in mortise-shaped bone groove-plasty and Akin osteotomy on the first toe for hallux valgus correction, is a stable and effective operative approach, especially for HV correction in the patients without osteoporosis. However, a further and larger clinical observation is needed.

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**Author Contributions**

Xin Jiao and Yaokai Gan contributed equally to this manuscript and should be considered the co-first authors. Yaokai Gan designed the surgical approach, conceived the study and performed firstly this technique in clinic. Xin Jiao followed up with the patients, collected the data and wrote this manuscript. Xin Jiao and Yiming Li analyzed the data. Chen Xu and Dingwei Shi assisted to perform surgeries. Jie Zhao and Kerong Dai supervised the performance of surgeries. Zengguang Wang and Xin Sun helped to analyze the data and interpret the results. All authors read and approved the final manuscript.

**Supporting Information**

Additional Supporting Information may be found in the online version of this article on the publisher’s web-site:

- Appendix S1. Supporting Information
- Appendix S2 Video 1.

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