Supramalleolar Fornix Osteotomy Combined Fibular Segmental Resection for Varus Ankle Osteoarthritis

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Research

Keywords: varus deformity, ankle arthritis, supramalleolar osteotomy, fornix, fibular segmental resection

Posted Date: February 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-189247/v1>

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Abstract

Background: To investigate the safety and clinical effect of supramalleolar fornix osteotomy combined with fibular segmental resection in the treatment of varus ankle osteoarthritis (VAO).

Methods: from July 2014 to July 2020, 38 patients with Takakura stage II - III VAO in Affiliated Hospital of Chengdu University were retrospectively analyzed, including 31 males and 7 females, 21 left ankles and 17 right ankles. They were divided into open osteotomy group (21 cases) and fornix osteotomy group (17 cases). According to the American Society of foot and ankle surgery ankle and hindfoot score (AOFAS) and visual analogue scale (VAS) for pain function and pain score; weight-bearing ankle acupoints and lateral X-ray imaging evaluation.

Results: 38 patients were followed up for 16-54 months (mean 41 months). The healing time of the supramalleolar osteotomy group (3.33 ± 0.90 months) was significantly shorter than that of the open osteotomy group (6.09 ± 1.74 months) ($t = -5.932$, $P = 0.000$). The postoperative FAS score of fornix osteotomy group (85.65 ± 6.49) was significantly better than that of open osteotomy group (63.05 ± 6.42), and the postoperative VAS score of fornix osteotomy group (2.12 ± 1.05) was significantly better than that of open osteotomy group (4.38 ± 1.60) ($P < 0.05$). The improvement of anterior angle of distal tibia, talus inclination angle and talus lateral displacement in the fornix osteotomy group was significantly better than that in the open osteotomy group ($P < 0.05$); the postoperative lateral angle of distal tibia in the fornix osteotomy group was $82.05 \pm 1.74^\circ$ on average, and that in the open osteotomy group was $80.17 \pm 1.34^\circ$ on average, with no significant difference between the two groups ($P > 0.05$).

Conclusion: The treatment of VAO with supramalleolar fornix osteotomy combined fibular segmental resection can effectively solve the anterior and talus lesions. The deformity correction around CORA can avoid the lateral displacement of the talus and effectively reduce the incidence of postoperative ankle degeneration. Short term follow up convinced better function restoration compared with open supramalleolar osteotomy.

Introduction

Ankle arthritis (AOA) accounts for about 1% of all the people [1]. Talus varus or valgus tilt occurs in 60% of the patients after ankle trauma [2]. Ankle instability, intra-articular cartilage damage, iatrogenic fracture reduction and so on will lead to biomechanical and soft bone cell biological abnormalities of the ankle joint, and eventually degenerate to form AOA [3, 4]. The onset of AOA is usually 12–15 years earlier than that of hip and knee joint, so the long-term effect is emphasized in the treatment [5]. Takakura et al. [6, 7] reported that supramalleolar open osteotomy has achieved good results in the treatment of varus ankle osteoarthritis (VAO), which can improve the posterior foot line, relieve ankle pain and delay joint degeneration. However, in our clinical work, we found that there are some problems in the treatment of VAO with open supramalleolar osteotomy, such as insufficient treatment of medial and lateral degeneration of anterior malleolus and tibiotalar joints, talus lateral displacement caused by non rotation

of angulation (Cora) correction, difficulty in correcting talus tilt, and so on. Anterior supramalleolar fornix osteotomy combined with fibular segmental resection can effectively deal with the tibiotalar joint lesions and correct the deformity around Cora with satisfactory clinical effect. In order to determine the safety and clinical effect of supramalleolar fornix osteotomy combined with fibular segmental resection in the treatment of VAO, 35 patients with VAO treated by supramalleolar open osteotomy and fornix osteotomy in the Affiliated Hospital of Chengdu University were compared and analyzed.

Methods

1.1 general data: retrospective analysis of patients with VAO who received osteotomy and orthopedic treatment in Affiliated Hospital of Chengdu University from July 2014 to July 2020. Inclusive criteria: 45–65 years old, varus ankle arthritis, anterior tibial angle (TAS) $\leq 85^\circ$, Takakura classification stage II-III [6], tibiotalar articular cartilage preservation $> 50\%$, simple coronal varus deformity, supramalleolar opening or fornix osteotomy correction. Exclusion criteria [8]: Previous peri ankle fracture or deformity surgery history, severe medial ankle wear requiring intra-articular osteotomy, Takakura stage IV ankle arthritis, posterior foot instability unable to recover through ligament reconstruction, genu derived ankle varus, peri ankle infection, severe vascular and neurological diseases, Charcot osteoarthritis.

Thirty eight patients were included in this study, including 31 males and 7 females, 21 left ankles and 17 right ankles. According to the osteotomy methods, they were divided into two groups: fornix osteotomy (FOT) group (n = 17, male 14, female 3, mean age 60.59); open osteotomies (OOT) group (n = 21, male 17, female 4, mean age 60.86). The general information of the two groups is shown in Table 1. There is no significant difference in gender composition, age, height and body mass index, anterior ankle osteophyte and other general information between the two groups ($P > 0.05$).

Table 1
Comparison of general data between supramalleolar open osteotomy and fornix osteotomy

	Supramalleolar open osteotomy(n = 17)	Open osteotomy group(n = 21)	P
Gender(F /M)	3/14	4/17	1.000
Age(Y)	60.59 ± 1.80	60.86 ± 1.49	0.618
Left and right side(L/R)	10/7	11/10	0.750
Body mass index(kg/m2)	20.94 ± 1.68	21.29 ± 1.45	0.502
Takakura classification(Ⅱ/Ⅲ)	7/10	7/14	0.740
OA/TOA	4/13	9/12	0.307
Diabetics	3/14	4/17	1.000
Smoking	3/14	8/13	0.282
Anterior ankle osteophyte(with/without)	14/2	18/3	1.000

1.2 Treatment:

1.2.1 Preoperative preparation: Smoking patients strictly prohibit smoking after hospitalization, diabetic endocrinology consultation to help control blood sugar. (1) Clinical examination: standing position assessment of the overall lower limb strength line, recording the patient's ankle active and passive activity, local pain position, inside and outside, front and rear drawer experiments to clarify ankle stability. (2) Imaging examination: preoperative X-ray examination includes the full length of double lower limb weight, ankle weight positive side position, rear foot weight long axis (long axial view radiographs) (10); Clinical determination of ankle arthritis malformation site, type, CORA position, back foot force line, external ankle ligament relaxation degree after determining the surgical program.

1.2.2 Surgical method: lumbar or full hemp, recline position, the affected limb with inflatable hemostatic belt (pressure 260 mmHg, 34.66Kpa), hemostatic belt inflated 30 minutes before the intravenous application of antibiotics to prevent infection.

(1) Open osteotomy group (Fig. 1): Surgery using the ankle inside the arc inlet, sharp separation of the inner ankle above the bone membrane, the front and back edge of the tibia inserted Hohmann pull hook to protect the tibia front and rear nerve blood vessel bundle. (1) 10mm into 2 2mm kT needles on the ankle line to protect the far end joint surface of the tibia. (2) Place the bone-osteotomy guide needle, 3cm above the inner ankle line into the needle facing down the joint above the phosphoric joint 1cm. (3) After accurate perspective positioning, a pendulum saw cut bone is used at a depth of 2cm. (4) The thin bone knife slowly amputated the bone, the perspective determines the distance from the fibula of the tibia cut

5mm part, insert the step bone knife gradually open, retain the hinge lateral bone tissue continuity. (5) ankle front side position, rear foot long axis X-ray perspective to determine the force line, generally maintain with the bone outside the turn of 5 degrees, the outer end of the shin bone joint surface turned 3 degrees by the inner ankle front and rear mound into the knuckle needle temporary fixation, bone cut gap > 10mm filled with allogeneic bone implants, placement of the inner anatomy locked steel plate (High, Shandong). After the internal fixation is completed, the ankle roll-over and front drawer experiments, such as external ankle instability, are reinforced with improved Brostrom rivet repair techniques. Open osteotomy group patients did not do fibula osteotomy, do not place drainage, stitch the wound, thick dressing covering the wound, elastic bandages pressurized bandage.

(2) Fornix osteotomy group (Fig. 2): the use of ankle front and center inlet, along the ½ long extension and toe extension tendon gap into, the inner side pull to protect the front nerve blood vessel bundle, open the ankle sac, clean the front ankle, bone - inner ankle, outer ankle gap, bone neck growth bone. Local cartilage dressing and micro-fracture molding from joint de-variant line. Sharp separation of the upper bone membrane of the ankle, the inner and outer sides of the tibia inserted Hohmann pull hook to protect soft tissue. (1) Placement of bone-osteotomy guide needle: the CORA point located under the ankle or away from the bone is positioned at 5mm on the ankle line, into a 2.5mm kT needle to determine the center of the fornix-cut bone rotation. (2) fornix osteotomy: placement of the collar needle locator, using a diameter of 2.5mm drill bit for ankle fornix osteotomy, bone radius of 3cm; (3) Outer ankle osteotomy: 1 to 2 cm above the arc extension line of the tibia fornix to carry out fibula osteotomy (note to protect the lower tibia joint), remove 5mm bone segment, bite bone pliers crushed into particle bone pieces after partial filling back planting. (4) Rotating orthopaedics: self-heeled bone into the 4mms needle, fixed heel-distance-shin bone far end, external rotation correction of the tibia far end joint surface deformity. (5) the front side position, rear foot long axis X-ray perspective determined after the foot outside the turn of 5 degrees, the placement of pressurized screws and the far end of the front tibia anatomy locked steel plate (Vigao, Shandong), the outer ankle osteotomy is not fixed. External ankle ligament instability repair technology, wound stitching technology and the inner open bone osteotomy.

Postoperative treatment: anesthesia wakes up immediately after the beginning of lower limb muscle contraction exercises, limb elevation promotes swelling and subsidence, encourages ankle stretching activity, drug anticoagulant prevention of deep vein thrombosis, open bone osteotomy 6 weeks after surgery, fornix osteotomy 2 weeks after the start of partial weight-taking activities, X-ray review prompts bone osteotomy after the start of full weight activity and gait exercise.

1.3 clinical follow-up: Monthly outpatient review and record the American Orthopedic foot and ankle score (FAS) ankle and hindfoot score [15]. Three months after the operation, the weight-bearing ankle acupoints and lateral X-ray examination were performed. I. X-ray measurement indexes of ankle acupoints: (1) tibial anterior surface angle (TAS): the angle between the distal articular surface of tibia and the medial side of tibial mechanical axis [16]. (2) Talar tilt angle (TTA): the angle between the articular surface of distal tibia and the surface of talar vault. (3) Lateral talus migration (LTM) [17]: the distance between the mechanical axis of talus and that of tibia. II. Lateral measurements included: tibial lateral surface angle (TLS): the

angle between the distal articular surface of the tibia and the anterior mechanical axis of the tibia. The imaging measurement was completed by the second author alone, and repeated 3 months later. The difference was ICC > 0.85.

1.4 statistical analysis: SPSS 19.0 software package was used for statistical analysis. The count data were compared by chi square test. Measurement data were expressed as mean $\pm$ standard deviation, and independent sample t test was used for comparison between groups. $P < 0.05$ was statistically significant.

Results

38 cases of VAO patients were successfully completed supramalleolar osteotomy, all patients did not appear postoperative wound healing, infection, venous thrombosis and other complications. All the 38 patients were followed up for 15–51 months (mean 36 months). The average healing time of the fornix osteotomy group was 3.33 ± 0.90 months (2–4 months), and that of the open osteotomy group was 6.09 ± 1.74 months (3–8 months). The healing time of the fornix osteotomy group was significantly shorter than that of the open osteotomy group ($t = -5.932$, $P = 0.00$). In the fornix osteotomy group, 17 patients were treated with osteochondral microfracture. There was no significant difference between the two groups ($\chi^2 = 0.486$, $P = 0.273$). There were 3 cases in the fornix osteotomy group and 5 cases in the open osteotomy group. There was no significant difference between the two groups ($\chi^2 = 0.709$, $P = 0.478$).

2.1 clinical follow-up (Table 2): there was no case of ankle instability at the last follow-up; in the open osteotomy group, 5 cases (23.8%) had ankle degeneration (all Takakura I progressed to Takakura II), and 3 cases had anterior ankle impingement (no reoperation intervention). There was no significant difference in preoperative FAS, range of motion and VAS scores between the two groups ($P > 0.05$); the postoperative FAS score of fornix osteotomy group (85.65 ± 6.49) was significantly better than that of open osteotomy group (63.05 ± 6.42). Postoperative VAS score: the average of fornix osteotomy group was 2.12 ± 1.05 , the average of open osteotomy group was 4.38 ± 1.60 , the pain improvement of fornix osteotomy group was significantly better than that of open osteotomy group ($P = 0.000$). At the last follow-up, the range of motion of ankle joint was $47.00 \pm 6.26^\circ$ in the fornix group and $26.62 \pm 4.67^\circ$ in the open osteotomy group ($P = 0.000$).

Table 2
Imaging evaluation of ankle joint in open osteotomy group and fornix osteotomy group

Group	Preoperative			Postoperative		
	FAS	Activity	VAS	FAS	Activity	VAS
Fornix osteotomy group(n = 15)	51.13 ± 6.13	29.27 ± 7.15	5.13 ± 1.41	88.47 ± 4.82	44.00 ± 3.72	2.40 ± 0.74
Open osteotomy group(n = 20)	47.05 ± 6.19	26.80 ± 5.15	5.85 ± 0.99	65.25 ± 9.24	28.80 ± 3.29	4.30 ± 1.30
T	1.939	1.189	1.772	8.843	12.795	5.065
P	0.061	0.243	0.086	0.000	0.000	0.000

2.2 imaging evaluation (Table 3): there was no significant difference in preoperative TAs, TTA, LTM and TLS between the two groups ($P > 0.05$). The improvement of TAs, TTA and LTM in the fornix osteotomy group was significantly better than that in the open osteotomy group ($P < 0.05$); the TLS fornix osteotomy group had an average of $82.05 \pm 1.74^\circ$ and the open osteotomy group had an average of $80.17 \pm 1.34^\circ$ after operation, and there was no significant difference between the two groups ($P > 0.05$)

Table 3
Radiographic comparison of post-surgical ankle X-ray 35 cases between fornix and open osteotomy groups

	Supramalleolar open osteotomy(n = 15)		Open osteotomy group(n = 20)		P
	Preoperative	Postoperative	Preoperative	Postoperative	
TAS($^\circ$)	82.36 ± 2.42	92.32 ± 1.62	81.14 ± 2.36	88.37 ± 1.71*	0.03
TTA($^\circ$)	5.38 ± 2.46	1.02 ± 0.25	5.62 ± 2.16	2.24 ± 1.59*	0.00
LTM(mm)	-	0.05 ± 0.03	-	2.62 ± 0.08*	0.00
TLS($^\circ$)	82.56 ± 3.41	83.11 ± 2.14	82.68 ± 3.24	81.45 ± 2.57*	0.56

Discussion

Different from primary osteoarthritis of hip and knee, AOA is mainly caused by trauma [18]. Saltzman et al. [18] pointed out that 70% of advanced AOA were traumatic, including 37.0% of ankle fractures and 28.3% of ankle sprains. Stufkens et al. [19] systematic analysis showed that 60% of patients developed traumatic arthritis in the long term after ankle trauma; ankle fusion or joint replacement surgery is usually required for advanced ankle arthritis [20]. With the further understanding of pathophysiology and biomechanics of ankle arthritis, as well as the progress of surgical technology, supramalleolar osteotomy has made extensive progress in the treatment of early VAO. The main indications are Takakura stage II-III [6] and mid-term ankle arthritis with more than 50% tibiotalar articular cartilage reserved. The purpose of

supramalleolar osteotomy is to transfer the lower limb load line to the relative normal cartilage area of the lateral ankle joint, restore the talus load center, correct the shear stress of the talus loaded obliquely [21], rearrange the posterior foot line, and improve the triceps torque of the leg. Supramalleolar osteotomy can preserve the patient's own joint, reduce pain, improve ankle function, restore physical activity and delay the progress of ankle arthritis [21].

3.1 varus ankle arthritis and Cora

Cora of most patients with VAO is close to ankle point or located in ankle joint [22]. Open or closed supramalleolar osteotomy without Cora will lead to horizontal displacement of the mechanical axis of the distal end of the osteotomy. For severe supramalleolar deformity, additional horizontal correction should be considered to avoid postoperative ankle joint load and abnormal appearance of the hindfoot. The fornix osteotomy with the osteotomy line passing through Cora and rotating around this point can avoid poor correction of force line and load [23].

3.2 clinical effect of supramalleolar open osteotomy:

The open osteotomy of the medial and superior malleolus is a simple operation, which can correct the deformity of $< 10^\circ$ varus ankle arthritis and sagittal deformity of the ankle. Takakura et al. [6] initially reported 18 cases (18 ankles) of VAO treated by open supramalleolar osteotomy, with an average follow-up of 6 years and 11 months. The results were excellent in 6 ankles, good in 9 ankles and fair in 3 ankles; 7 cases of fibrocartilage regeneration were found in 10 patients during the second stage arthroscopic examination. Knupp et al. [24] followed up 94 patients with supramalleolar osteotomy for 43 months, the FAS score improved from 55.6 ± 17.2 to 72.8 ± 18.9 , the VAS score decreased from 4.6 ± 1.9 to 2.8 ± 2.3 , and the improvement of Takakura grade of joint degeneration was not obvious. Hongmou et al. [12] followed up 41 patients with Takakura stage II and III varus ankle osteotomy (average 36.6 months). The average fracture healing time was 3.8 months. The FAS score was improved from 50.8 ± 13.6 to 83.1 ± 9.6 , and the Maryland score was improved from 58.3 ± 12.0 to 81.6 ± 6.0 .

This study found that there are problems with open bone osteotomy on the ankle: (1) inadequate treatment of lesions in the joints: Knupp and others recommended that the ankle osteotomy first perform arthroscopic examination and clean-up, however, the fornixstic clinic rarely completes ankle arthroscopic and open bone osteotomy surgery in the first phase. In this study, the average preoperative ankle activity of 20 patients in the open bone-osteotomy group was 21.43 degrees, and the postoperative average was 26.62 degrees, and the improvement was not obvious, which was considered to be related to the unprocessed front ankle-fare bone impact. (2) Bone osteotomy open gap needs bone implantation: 20 patients in this group were performed with allogeneic bone transplantation, with an average healing time of 6.25 ± 1.33 months (3 to 8 months), and no allogeneic bone transplant-related excreting reactions occurred after surgery. (3) Outward shift from bone center: after surgery from bone outward shift average 2.67 ± 0.40 mm, compared to the fornix bone group (average 0.04 ± 0.02 mm) outward shift is obvious, suggesting poor recovery of the spacing mechanical axis. (4) Tilt from bone: open exostomy pre-surgery bone tilt average 5.62 degrees, postoperative residual tilt 2.24 degrees from the bone, significantly larger

than the fornix osteotomy group (1.02 degrees), suggesting that the simple inner open amputee bone tilt correction is not good, may be related to the lack of internal descision tissue clean-up and the relaxation of the outer ankle ligament complex. (5) Outer ankle osteotomy: Hongmou, etc., believes that the fibula osteotomy adaptation in the inner open osteotomy includes: the angle of the shin is reduced by 5 degrees compared to the other ankle, the presence of rotating deformities in the fibula or blocking the matching recovery of the tibia joint, > 10 degrees of deformity correction usually requires the fibula osteotomy. None of the 20 open bone osteotomy patients in this group had an external ankle osteotomy, and the POST-operative follow-up FAS score of 63.05 ± 6.42 was significantly lower than the 83.1 ± 9.6 points reported by Hongmou and others, but Hongmou and other studies showed that although the outer ankle osteotomy significantly improved the patient's bone tilt and spacing angle, it had no significant effect on ankle function recovery. Therefore, the recovery of the function of open bone osteotomy group in this study is lower than reported in the literature and may be related to the comprehensive factors such as inadequate treatment of lesions in the joint, emigration from the bone, and tilt of residual bone.

3.3 Clinical effect of joint fibula section removal of the fornix osteotomy on the ankle:

Fornix osteotomy is suitable for CORA close to ankle or in-joint malformation, orthopaedic range is large, bone osteotomy risk is low, but fornix osteotomy is only a single plane orthopaedic. Chopra and others recommend that the fornix osteotomy treat VAO, usually combined with the fibula coronary position oblique or short cut bone. However, Lee and others pointed out that for VAO patients with widening ankle cavities (inner ankle wear, loose external ligaments) after the implementation of the outer ankle bone osteotomy is easy to aggravate the widening of the ankle cavity. In this study, patients with severe internal ankle wear were excluded, and external ankle instability resulted in external ankle-from bone gap widening patients with Brostrom's external ankle ligament strengthening to restore outer ankle-bone stability. The front-way fornix osteotomy can directly deal with internal lesions in the ankle, surround the CORA orthopaedics to avoid poor ankle strength after surgery, and after the excision of the fibula section, the patient can rely on the combined stability of the lower tibia and the dynamic structure of the ankle muscles to achieve postoperative ankle cavity self-adaptation, which is conducive to the recovery of the patient's ankle biometric structure.

This study found that the post-fornix bone osteotomy FAS score (85.65 ± 6.49) was significantly better than that of the open bone osteotomy group (63.05 ± 6.42). Postoperative VAS score comparison: fornix osteotomy group averaged 2.12 ± 1.05 , open osteotomy group averaged 4.38 ± 1.60 , fornix osteotomy group pain improvement was better than open bone osteotomy group ($P < 0.000$). The improvement of the front corner of the outer end of the tibia of the postoperative fornix bone group, the tilt angle from the bone, and the outward shift of the bone were significantly better than that of the open osteotomy group ($p < 0.05$); 82.05 ± 1.74 degrees, open bone-osteotomy group average 80.17 ± 1.34 degrees, relatively no significant difference between groups ($p > 0.05$). The postoperative follow-up function of the fornix osteotomy group is far better than that reported by Knupp and other literature, and also significantly better than that reported in the recent literature of Xu and so on (21 cases are Takakura 3B, postoperative FAS score average 74.8 ± 11.5 , VAS score average 2.5 ± 1.9).

In short, the ankle fornix osteotomy joint fibula section excision technology to treat VAO can effectively solve the ex-ankle and tibia-distance joint lesions, while rotating orthopaedics around CORA to avoid displacement from the bone side, improve the distribution of the load in the VAO ankle and then delay the ankle degenerate, the recent effect is better than the simple ankle open osteotomy;

Declarations

Ethics declarations

Ethics approval and consent to participate

The Affiliated Hospital of Chengdu University granted approval, and informed consent was obtained for all participants included in the study .

Consent for publication

Participants' consent to publish was granted.

Competing interests

The authors declare that they have no competing interests.

Role of funding source

Sichuan Science and Technology Program Project 2018JY0354

Chengdu Medical Research Project 2020068

Contributions

Nengyuan Weng: Conceptualization, Validation, Data curation, Formal analysis, Investigation, Methodology, Writing - review & editing. **Kainan Li:** Conceptualization, Investigation, Writing - review & editing. **Hai Lan:** Conceptualization, Investigation, Methodology, Validation, Supervision, Writing-review&editing. **Zhengxia Hu:** Conceptualization, Validation, Writing - review & editing. **Xuan Liu:** Writing - review & editing. All authors contributed to and have approved the manuscript.

Acknowledgments

We thank the Affiliated Hospital of Chengdu University students for participating in the training, testing and data collection for this project

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Figures

Figure 1

Preoperative X-ray and intraoperative supramalleolar perspective of a 63 year old man with left ankle varus arthritis undergoing open osteotomy A. Preoperative ankle weight-bearing X-ray showed Takakura

type B varus ankle arthritis. B. insert osteotomy positioning guide pin, open the osteotomy space, insert step bone knife, keep the distal tibial articular surface everted 3 degrees. C. place anatomical locking plate on the medial side of the distal tibia after maintaining the osteotomy position with Kirschner wire

Figure 2

Preoperative X-ray and intraoperative perspective of supramalleolar fornix osteotomy in a 56 year old female with right ankle varus arthritis A. Preoperative ankle weight-bearing anteroposterior X-ray showed Takakura type II varus ankle arthritis. B. Cora osteotomy positioning guide needle was inserted. C. fornix osteotomy was completed to keep the distal tibial articular surface everted 3 degrees. Kirschner wire maintained the osteotomy position. D. anteroposterior X-ray fluoroscopy was performed after placement of compression screw and anatomical locking plate of distal radius