



Functional outcome following closed reduction and percutaneous osteosynthesis of distal tibia articular fractures in children

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Closed reduction and percutaneous osteosynthesis is an alternative to the open procedure for articular fractures of distal tibia of children.

38 patients were retrospectively reviewed. The measured parameters were : the score of Gleizes and the discrepancies between preoperative radiographic and CT scan measurements and postoperative radiographs.

A significant correlation was found between the gap and the step-off in preoperative radiographic and CT scan. A significant decrease of the gap and step-off displacement was noticed after surgery. The Gleizes scoring showed 35 good results, 2 average results and 1 poor result.

Percutaneous fixation of ankle articular fractures in children is a simple and effective treatment giving similar results to open techniques while minimizing the risk of joint stiffness and healing complications. Growth complications are comparable with both techniques.

Keywords : distal tibia fracture ; percutaneous osteosynthesis ; children ; tillaux ; Mac farland.

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The institutions ethics board approved the study. Informed consent was obtained from all individual participants included in the study.

INTRODUCTION

Articular fractures of the distal tibia in children include triplanes, MacFarland and Tillaux fractures. They occur during closure of the distal tibia growth plate, which starts at the “Poland Hump”, and extends initially in a medial direction and ends at the anterolateral edge (15), except for MacFarland fractures that can occur in younger children.

This progressive closure process can initiate different kinds of fractures. The standard indication for surgical treatment is a fracture gap or a step-off displacement of more than 2mm (6). The reference treatment is open reduction and fracture fixation (6,12). In order to minimize the surgical approach, techniques using closed reductions guided either by arthroscopy (11) or controlled by arthrography have been described (5). A minimally invasive technique,

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combining a reduction of the fragments by external manoeuvres with percutaneous osteosynthesis has been developed (18). The main objective of this study has been to determine the functional and radiological outcome following percutaneous fixation of articular fractures of distal tibia in children and to compare our results with the data published in the literature data. The secondary objective has been to compare the measurements of the fracture gap and the step-off displacement obtained preoperatively with standard X-Rays and with CT scan.

PATIENTS AND METHODS

For this retrospective study, achieved at the Strasbourg University Hospital from 2002 to 2012, we have reviewed all the patients having been treated for a distal tibia fracture with percutaneous fixation. Reduction was achieved by external manoeuvres (so called “boot removal technique”, combined with varus or valgus movements on the ankle). If the reduction was considered insufficient, additional correction can be obtained with a percutaneous pin (joystick technique). The objective of an ideal osteosynthesis is positioning of the cannulated screws perpendicularly to the fracture plane, but without damaging the growth plate in the case of Mac Farland fractures. Therefore, a thorough preoperative planning is mandatory, guided by the X-Rays or by a CT scan, for the most complex cases. Quality of the reduction was assessed on the fluoroscopic controls. The reduction criterion was a residual fracture gap of less than 1mm. When the reduction was considered satisfactory, the fracture could be stabilized and type of fixation was left to the discretion of the surgeon. The surgical approach was shown in illustration 1, 2 and 3.

All fractures were then immobilized by a below the knee cast for a period of 6 weeks. The mean follow-up period was 32.3 weeks.

The results were classified into 3 categories according to the classification established by Gleizes et al (8) : – Good : no pain, no stiffness, no walking impairment, no arthritis, – Fair : moderate pain, stiffness and / or discomfort in walking, without arthritis – Poor : severe pain and / or important stiffness and / or limping and / or arthritis.



Figure 1. — Preoperative X rays and CT scanner



Figure 2. — Fluoroscopic view of external reduction manoeuvres before osteosynthesis)



Figure 3. — Control X rays at 1 year postoperative)

A functional analysis was conducted using the modified Weber protocol (10) Illustration 4. – Results are considered excellent when the sum is equal to 0. Results are considered good if the sum is between 1 and 2 and if there is no joint incongruity or arthritis signs at the ankle joint – Results are considered poor if the sum is equal or greater than 3.

- I. Pain
 - A. No pain 0
 - B. Slight pain with excess activity 1
 - C. Mild pain with normal activity 2
 - D. Pain with standing 3
 - E. Pain at rest 4
- II. Walking
 - A. Normal walking 0
 - B. Can work normally but is restricted in some strenuous activities 1
 - C. Slight limp 2
 - D. Partially disabled 3
 - E. Totally disabled and must change jobs 4
- III. Activity
 - A. Fully perform the job 0
 - B. Can work normally but is restricted in some strenuous activities 1
 - C. Normal work but very limited in his activity 2
 - D. Partially disabled 3
 - E. Totally disabled and must change jobs 4
- IV. Radiographs
 - A. Anatomically perfect with no arthritis 0
 - B. Anatomically perfect with slight calcification in the ligaments but no arthritis 1
 - C. Anatomical disruption on the medial side 2
 - D. Anatomical disruption laterally with arthritis present 3
 - E. Step off in the joint with arthritis 4
- V. Ankle Joint Function
 - A. Full function, both sides equal 0
 - B. Loss of motion, 10° 1
 - C. Loss of motion greater than 10° but dorsiflexion possible to 95° 2
 - D. Motion less than 10° but dorsiflexion possible to 95° 3
 - E. Stiff foot 4
- VI. Subtalar Joint
 - A. Full function, both sides equal 0
 - B. Slight diminution 1
 - C. Limitation less than half as compared to the sound side 2
 - D. Limitation more than 50% compared to the sound side 3
 - E. No motion 4

Figure 4. — The modified Weber protocol

Statistical Analysis

For quantitative variables, in case of normal distribution, the correlation analysis has used the Pearson coefficient and the comparison between groups has been made with Student t test or analysis of variance according to the number of groups. In case of non-normal distribution, the correlation analysis has used the Spearman coefficient and the comparison between groups has been made with non-parametric analysis ranks as Mann-Whitney or Kruskal and Wallis tests, according to the number

of groups. For qualitative variables, the statistical comparison has used the Chi-square test or the Fisher exact test, according to the number of patients after eventual regrouping. The threshold of signification has been established at 0.05. The analysis was done on StatEL Software. The study received approval of the ethics committee.

RESULTS

The records of 38 patients were analyzed in this study. Demographic and radiographic data are reported in Table I.

Of the 16 triplane fractures, 10 were fixed with screws inserted in the frontal plane, 1 with screws in the sagittal plane and 5 with screws both in the frontal and the sagittal plane. 10/16 patients underwent hardware removal in an average delay of 11.6 months.

Of the 8 Tillaux fractures, 4 received a screw fixation in the frontal plane and 4 were treated with adjustable locked threaded pins according to technical described by Gicquel et al (7). All the patients treated with locked pins underwent hardware removal within a mean period of 2.2 months. 2 patients treated with screw fixation had the hardware removed within 9.86 months.

Of the 14 MacFarland fractures, 7 were fixed with screws in the frontal plane (including 6 epiphyseal screws and 1 screw crossing the growth plate) and 7 were treated with pin fixation (including 5 Kirschner wires crossing the growth plate and 2 locked threaded pins also crossing the growth

Table I. — Demographic data of the series

	Triplane	Tillaux	MacFarland
Patient	16	8	14
Gender			
Male	11	4	7
Female	5	4	7
Mean Age (years) +/- standard deviation	14,1 +/- 0,59	14,6 +/- 1,28	13,0 +/- 2,75
Laterality			
Left	12	6	8
Right	4	2	6
Mean time for hospitalisation (days)	2,4	1,62	2,85

Table II. — Demographic data of the series

		Male	Female	<i>p</i>
Triplane	Patient	11	5	NS
	Mean Age +/- Standard-deviation	14,3 +/- 0,53	13,7 +/- 0,47	NS
Tillaux	Patient	4	4	NS
	Mean Age +/- Standard-deviation	15,3 +/- 0,49	13,2 +/- 1,49	NS
MacFarland	Patient	7	7	NS
	Mean Age +/- Standard-deviation	13,2 +/- 2,85	12,7 +/- 2,60	NS
Total	Patient	22	16	NS
	Mean Age +/- Standard-deviation	14,1 +/- 2,0	13,3 +/- 1,8	0,046

Table III. — Preoperative radiographic and CT scan fracture displacement measurements

Types of fractures	X-Ray	CT-Scan	DifferenceX-Ray/CT-Scan
Triplane (14 fractures)			
Mean step-off (mm) +/- standard-deviation	1,06 +/- 0,61	1,42 +/- 0,85	0,32 +/- 0,81
Mean gap (mm) +/- standard-deviation	2 +/- 0,67	3,62 +/- 1,27	1,62 +/- 1,05
Tillaux (3 fractures)			
Mean gap (mm) +/- standard-deviation	1,75 +/- 0,58	2,42 +/- 0,29	0,67 +/- 0,76
MacFarland (4 fractures)			
Mean step-off (mm) +/- standard-deviation	1,25 +/- 0,5	2,43 +/- 1,37	0,40 +/- 1,01
Mean gap (mm) +/- standard-deviation	1,25 +/- 0,4	2,42 +/- 1,19	1,17 +/- 1,01

Table IV. — Pre- and postoperative radiological and functional data

	Triplane	Tillaux	MacFarland
Mean of the radiographic gap (mm)			
Preoperative	2	2,5	2,1
Postoperative	0,12	0,25	0
Mean of the step-off (mm)			
Preoperative	1,3	1	1
Postoperative		0	
Score of Gleizes			
Good	14 (87, 5%)	8 (100%)	13 (92,9%)
Fair	2 (12, 5%)	0	0
Poor	0	0	1 (7,1%)
Modified Protocol Weber			
Excellent	13 (81, 2%)	8 (100%)	13 (92,9%)
Good	3 (18, 8%)	0	0
Poor	0	0	1 (7,1%)

plate). All the screws have been removed in a mean delay of 7.2 months and all the pins were removed in a mean delay of 2.16 months.

Comparison according gender and age at trauma

The age at onset of fracture according to gender appeared statistically significant ($P = 0.046$): 14.1 years +/- 2.0 years average age in boys compared to 13.3 years +/- 1.8 years in girls, the data are reported in Table II.

No significant difference in distribution between the types of fracture according to gender was found.

21 preoperative CT scans were performed to analyze fracture displacement. Data are shown in table III. The statistical analysis revealed a significant correlation between radiographic and CT scan preoperative measurements of the fracture gap ($P < 0.01$) corresponding to the formula : radiographic gap = 0.5 x CT scan gap. We also found

a significant correlation between the preoperative and postoperative step-off displacement measured by CT scan, corresponding to the following linear relationship : radiographic step-off displacement = 0.7 x CT scan step-off displacement.

Functional results according to the score of Gleizes and the Weber protocol are reported in Table IV.

Comparison of preoperative and postoperative radiographic measurements

We found a statistically significant decrease ($p < 0.00001$) of the postoperative fracture gap compared with the preoperative status. This measured gap decreased from 2.2 mm (+/- 1.2 mm) to 0.1 mm (+/- 0.4 mm) and never exceeded 1 mm. We also found a statistically significant ($p < 0.00001$) decrease of the postoperative radiographic step-off displacement compared with preoperative status. This displacement decreased from 1.6 mm (+/- 1.1 mm) to 0.2 mm (+/- 0.4 mm) and never exceeded 1 mm.

Complications

We encountered one case of distal tibia epiphysiodesis following a Macfarland type of fracture. The radiographic controls performed during follow-up showed no secondary displacement. We have noticed a medial tibia epiphysiodesis having led to a varus deformity of 17.9°. A surgical desepiphysiodesis according to the procedure described by Bollini et al. (2) was performed. The outcome was satisfactory.

DISCUSSION

In girls fractures occurred at an earlier age than in boys (151 months +/- 43 months versus 172 months +/- 34, $p < 0.01$). This difference, also found in the literature for Tillaux and triplane fractures by Ertl et al and by Chouldry et al, results from an earlier closure of the growth plate in girls (3.6). Chouldry et al also showed that triplane fractures (58 cases) occurred at an earlier age than Tillaux fractures (20 Tillaux) : 161.4 months +/- 20 versus 165.4 months +/- 18, $p = 0.010$) (3). The closure of the physis begins in the anteromedial part and extends

towards the anterolateral portion. This last part of the physis to get fused may be the location of a late physeal injury, as for the Tillaux fracture (6). We did not identify any significant differences in the distribution of fracture types according to gender. This could be due to the low number of patients for each type.

The primary criterion for adequate reduction is the lack of postoperative inter-fragment gap in order to avoid residual pain and epiphysiodesis bridges (6,14). The amount of initial displacement is not a risk factor for epiphysiodesis. The major criterion is the amount of postoperative inter-fragment gap (1). The proposed recommendation is to not leave an inter-fragment gap greater than 2 mm. A gap of more than 2 mm is usually due to a periosteal interposition which increases the risk for epiphysiodesis (1). The comparison of inter-fragment gaps measured on standard X Rays and on CT Scans consistently showed an underestimation of the radiological measurements compared to the CT Scan. We also found this underestimation in the study of Horn and al (9). In our protocol, the indication for surgical treatment was selected in case of a radiographic displacement greater than 1 mm. Thus, a displacement of 1 mm on a radiograph should require a surgical reduction. We recommend the use of the CT Scan only if the standard X Rays are unable to analyze properly the fracture topography and displacement, in order to anticipate the proper positioning of the osteosynthesis material.

For Mac Farland fractures, Cottalorda et al (4) had recommended a systematic open reduction in order to allow a perfect reduction under visual control and to avoid leaving a displacement greater than 1 mm. 48 Mac Farland fractures were treated with open reduction. The postoperative follow-up 3 months after surgery showed, according to the modified Weber protocol, 35 good results and 13 fair results (6 joint stiffness, 4 ankle pain, 4 healing difficulties, 1 limping). The long-term follow-up showed 45 good results, 2 fair results (1 adherent and 1 hypertrophic scar) and 1 poor result (angular deformity in varus of 6°). The extensive surgical approach, combined with arthrotomy, leads to a slower recovery with early joint stiffness, and favours adherent and hypertrophic scars. An

alternative to open reduction is a percutaneous reduction, assisted by ankle arthroscopy. Jennings et al had operated on 6 triplane fractures under arthroscopic control (11). All patients had taken over all of their activities within 14 weeks and no patient had a limited ankle mobility.

Duran et al (5) had treated 12 patients with Mac Farland fractures by percutaneous osteosynthesis with the help of an arthrography to control the reduction. The preoperative gap was about 2.8 mm and the postoperative gap was 0 mm in 8 cases, less than 1 mm in 3 cases and 2 mm in 1 case. Postoperative follow-up was considered good in 11 cases and 1 case was fair according to the Gleizes classification. This patient with a fair result had residual pain. In our series, the post reduction defect never exceeded 1 mm. The recovery period of the ankle mobility has been of about 2.8 months. This period is shorter than with open procedures. We have confirmed the absence of scar incident. According to the classification of Gleizes, we found 13 good results and one patient had a poor result, which is comparable to the series published by Duran et al⁽⁹⁾. Percutaneous treatment, while avoiding open arthrotomy, decreases significantly joint stiffness and healing complications. Based on the modified Weber protocol for Mac Farland fractures, we found 13 good results and one poor outcome, due to a medial tibial epiphysiodesis (20), these results are comparable to the reevaluation at a late stage of the series published by Cottalorda et al (4).

Rapariz et al (17) have studied the functional outcome of 35 triplane fractures. 15 patients were treated conservatively, 15 had an open reduction with internal fixation and 5 had a percutaneous osteosynthesis. Of all the patients, they noticed 34 results characterized as good or excellent and one graded as poor according to the Weber protocol. Kim has analyzed 14 fractures of the distal tibia (11 triplane and 3 Tillaux) (13). 6 percutaneous osteosynthesis and 8 open procedures have been achieved. The analysis according to the modified Weber protocol showed 13 excellent results and one graded as poor, due to narrowing of the joint space. These data are comparable to the series of 11 triplane fractures treated surgically by Tan with 7 open procedures and 4 percutaneous treatments

(19). The analysis by the modified Weber protocol showed that at 14.2 weeks follow-up, all the patients had an excellent result. Of the 11 patients, 6 had a joint stiffness and 4 had residual pain four weeks after cast removal.

In our series, for the 24 fractures including 16 triplane and 8 Tillaux fractures, we found, according to the modified Weber protocol, 21 excellent results and 3 good results. We found the same results as in the previously described series combining open procedures and percutaneous treatments. Thus, percutaneous treatment has a comparable efficacy compared to open procedures.

Pannier (16) has treated conservatively all displacements of less than 2 mm in 9 patients and, with open procedures all displacements of more than 2 mm in 10 patients. The results of functional analysis according to the criteria of Gleizes were all good.

We found the same results in our series, by performing a closed percutaneous treatment.

CONCLUSION

The treatment protocol combining external reduction manoeuvres with closed osteosynthesis is a minimally invasive surgical technique allowing a faster functional recovery, while minimizing scar complications. Our results demonstrate that this procedure achieves the same efficacy as open procedures

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