Concurrent ipsilateral Tillaux fracture and medial malleolar fracture in adolescence: management and outcome

quanwen yuan
Soochow University Affiliated Children's Hospital

Zhixiong Guo
Soochow University Affiliated Children's Hospital

Xiaodong Wang
Soochow University Affiliated Children's Hospital

Jin Dai
Soochow University Affiliated Children's Hospital

Fuyong Zhang
Soochow University Affiliated Children's Hospital

Jianfeng Fang
Soochow University Affiliated Children's Hospital

Chunhua Yin
Soochow University Affiliated Children's Hospital

Wentao Yu
Soochow University Affiliated Children's Hospital

Yunfang Zhen (✉ yfzhen@suda.edu.cn)
https://orcid.org/0000-0002-8457-265X

Research article

Keywords: adolescence, ankle, malleolar, tibia, Tillaux fracture

DOI: https://doi.org/10.21203/rs.3.rs-27907/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

Background

The concurrent ipsilateral Tillaux fracture with medial malleolar fracture in adolescence commonly suffer from high-energy injury, making treatment more difficult. The aim of this study was to discuss the mechanism on injury, diagnosis and treatment of this complex fracture pattern.

Methods

The charts and radiographs of six patients were reviewed. The functional was assessed by the American Orthopedic Foot and Ankle Society ankle-hindfoot scores.

Results

The mean age at operation was 12.8 years. The mean interval from injury to operation was 7.7 days. Five Tillaux fractures and all medial malleolar fractures were shown on AP plain radiographs. One Tillaux fracture and two cases with avulsion of posterolateral tibial aspect were confirmed in axial computerized tomography. Talar subluxation laterally with medial space widening in three, and syndesmotic disruption in one. There were five patients sustaining ipsilateral distal fibular fractures. All fractures, except nonunion in two medial malleolar fractures and in one Tillaux fracture, healed within 6–8 weeks. There was one case of osteoarthritis of ankle joint. The average AOFAS score was 88.7.

Conclusions

Computerized tomography is helpful in identifying the fracture pattern. Anatomic reduction and internal fixation of Tillaux and medial malleolar fracture was recommended to restore the articular surface congruity and ankle stability.

Background

Physeal injuries of the distal tibia are second in frequency to those of the distal radius and carry a high risk of complications. Tillaux fracture accounts for approximately 2.9–6.7% of the distal tibial epiphyseal fractures\[1, 2\]. It usually occurs in adolescents when the center and medial side of the distal tibial physis have been closed and the anterolateral quadrant fusion does not occur. The mechanism of injury involved external rotation of the foot contributing to the avulsion of the anterior inferior tibiotalar ligament(AITFL). The pediatric medial malleolar fractures (MMF) usually involved the growth plate, often Salter-Harris I or II fractures, and carried the highest risk of complication for the premature physeal closure(PPC) [3–5]. Whereas, fractures of other parts of the medial malleolus have received sporadic
attention in the literature for lower rate of growth disturbance and non-weightbearing area. However, the medial malleolus plays an important role in ankle stability as a bony restraint [6].

Isolated fractures, aforementioned, are usually suffering from indirect force with particular foot position. Direct or high-energy trauma to the ankle may result in special injury configurations. Recently, Gourineni and Gupta[7] reported that six out of eight Tillaux fractures had associated with talar subluxation (TS), lateral malleolar fractures. To our knowledge, there has been no report regarding to the combination of Tillaux fracture and MMF in adolescence. It was the purpose of this study to report the experience of a pediatric trauma center in an attempt to discuss its mechanism of injury, diagnosis, and treatment options.

**Methods**

This study was approved by the ethics committee of the Children's Hospital of Soochow University. Six cases of Tillaux fracture associated with MMF were treated from January 2015 to December 2018. The charts and radiographs of six patients were reviewed retrospectively. Clinical data, including age, sex, mechanism of injury, and methods of treatment were collected(Table 1). There were three boys and three girls, with a mean age at operation of 12.8 years (range, 12 to 14 years). The left side was involved in three and the right in three. One patient was hurt while falling down, three during sports of sliding or soccer, two in a motor vehicle accident. The mean follow-up was 11.7 months (range, 6 to 27 months).
Table 1
Patient demographic data

| No. | Gender | Age (y + m) | Interval (d) | Lateral | Cause | Associated Injuries | TMM | DT (mm) | SD | Treatment | Complications | Follow-up (months) | AO FA S |
|-----|--------|-------------|--------------|---------|-------|---------------------|-----|---------|----|-----------|---------------|-------------------|--------|
| 1   | F      | 14          | 3            | L       | traffic |                      |     |          |    | ORIF      | —             | 6                 | 96     |
|     |        | + 11        |              |         |        | S-H III             | 5.6 |          |    |           |               |                   |        |
| 2   | F      | 12          | 6            | R       | sliding | distal fibular Fx; TS |     |          |    | ORIF      | —             | 13                | 90     |
|     |        | + 9         |              |         |        | H-B                 | 8   | no       |    | P + S     |               |                   |        |
|     |        |             |              |         |        |                      |     |          |    |           |               |                   |        |
| 3   | M      | 14          | 5            | L       | traffic | distal fibular Fx    |     |          |    | ORIF      | —             | 8                 | 96     |
|     |        | + 11        |              |         |        | H-C                 | 2   | no       |    | P + S     |               |                   |        |
| 4   | F      | 12          | 5            | R       | sliding | distal fibular Fx, avulsion of PLTA, TS |     |          |    | ORIF      | No union of medial malleoli | 10                | 90     |
|     |        | + 1      |              |         |        | H-C                 | 9.4 | no       |    | P + S     |               |                   |        |

Fx, fracture; TS, talar subluxation; PLTA, posterolateral tibial aspect; ORIF, open reduction and internal fixation for Tillaux and/or medial malleolar fractures;

P + S, plate + screws for distal fibular fracture; TMM, type of medial malleolar fracture; DT, initial displacement of Tillaux fragment; SD, syndesmotic disruption. OA, osteoarthritis.
| No. | Gender | Age (y + m) | Interval (d) | Cause | Associated Injuries | TMM | DT (mm) | SD | Treatment | Complications | Follow-up (months) | AO FA S |
|-----|--------|-------------|--------------|-------|---------------------|-----|---------|----|-----------|---------------|-------------------|---------|
| 5   | M      | 13 +1       | 20           | R falling | distal fibular and S-H I epiphyseal Fx, TS | H-C | 8.2     | yes| Tract ion | Non union of Till au x and medial malleolari, instability, y, OA | 27     | 64     |
| 6   | M      | 12 +10      | 7            | L soccer | distal fibular Fx, avulsion of PL TA | H-C | 8.8     | no | ORIF | —              | 6     | 96     |

Fx, fracture; TS, talar subluxation; PLTA, posterolateral tibial aspect; ORIF, open reduction and internal fixation for Tillaux and/or medial malleolar fractures;

P + S, plate + screws for distal fibular fracture; TMM, type of medial malleolar fracture; DT, initial displacement of Tillaux fragment; SD, syndesmotic disruption. OA, osteoarthritis.

Anteroposterior (AP), lateral plain radiographs and computerized tomography (CT) were performed in all patients to identify the fractures. Axial CT views were reviewed for displacement of Tillaux fractures in the maximal gap section in millimeters and to identify the inferior tibiobular syndesmosis disruption (SD) and the avulsion of posterolateral tibial aspect (PLTA).

MMF were classified according to Salter-Harris epiphyseal injury (S-H) when the physis was involved.[8] Otherwise, Herscovici classification (H), based on the level of MMF, was used: type A, fracture being
avulsions of the tip; type B, between the tip and the level of the plafond; type C, at the level of the distal plafond of the tibia; type D, extended vertically above the plafond[6]. TS was considered if medial joint space of the ankle was greater than the superior ankle space in AP plain radiographs or coronal CT scans [8].

For Tillaux fracture, open reduction was performed through an anterolateral ankle approach and anatomical reduction was obtained and maintained by Kirschner wires (K-wires). Closed reduction and K-wires fixation were undergone for MMF. If necessary, open reduction and internal fixation (ORIF) of the fibular fracture was done with plate and screws. Postoperatively, a short-leg cast was applied and the patients were instructed not to bear weight for 6–8 weeks.

Functional assessment was by American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot scores which consists of pain (40 points), function (50 points), and alignment of the involved ankle (10 points) [9].

Results

Of six patients, five Tillaux fractures and all MMF were shown on AP plain radiographs. Tillaux fracture in one and avulsion of PLTA in two were confirmed in axial CT. AP plain radiographs showed TS laterally with medial space widening in three patients. In one patient, the axial CT showed SD. There were five patients sustaining ipsilateral distal fibular fractures.

All Tillaux fragments were rotated laterally and the mean initial displacement was 7 mm (range, 2.0 to 9.4 mm) in axial view. Out of six MMF, one was S-H III fractures, one H-type B and four H-type C. Both avulsion of PLTA had minimal displacement.

The mean interval from injury to operation was 7.7 days (range, 3 to 20 days). For Tillaux fracture, five cases were treated with ORIF with K-wires, and one without internal fixation owing to 20 days interval after injury for significant soft tissue compromise. For MMF, open reduction and K-wire fixation was underwent in S-H III fracture, five closed reduction and K-wire fixation for H-type B and C. One failed to be fixed due to technique error. Of the five fibular fractures, open reduction and fixation with plate and screws were needed to stabilize the ankle joint in three associated with TS laterally. Syndesmotic fixation was not used for SD and neither of the avulsion of PLTA was fixed for small fragment.

None of the patient suffered deep infection. All fractures, except two instances of nonunion in MMF and one in Tillaux fracture, healed within 6–8 weeks. All three patients with TS showed complete reduction of medial joint space post operation. Radiographs of this child without reduction of Tillaux and MMF demonstrated a valgus of ankle joint, hindfoot instability, and radiographic sign of osteoarthritis. Neither PPC nor leg length discrepancy developed in any of the patients.

The AOFAS score was 88.7 (64 to 97) at the final visit (Table 1). Typical cases were shown in Figs. 1, 2 and 3.
Discussion

We reported on case series of patients sustaining Tillaux fracture associated with MMF. This study showed that the mean AOFAS score of this complex fracture was 88.7, being comparable to the results reported in other series sustaining isolated fractures\[5, 10\].

In present series, most of the injury resulted from high-energy forces across the ankle joint. Even though the position of the foot immediately at the injury was uncertain, the external rotation forces be applied in all of the six cases and caused Tillaux fracture. When the force continued to be sufficient, the distal fibula will mostly appear a short oblique fracture and the posterior tibiofibular ligament was stretched to create the avulsion of PLTA, being similar to Volkmann fracture in adult\[11\]. In addition, PLTA will also result from plantar flexion force\[12\]. But this usually involves more displacement and a larger fragment. Extreme external rotation of the talus will create MMF in adolescence\[7, 13\]. In this series, four MMF lines lied adjacent and parallel to the level of distal tibial plafond. This may be the result of the impingement between the talus and the medial malleolus\[14\].

In general, the diagnosis of MMF and fibular fractures may be easily detected on plain radiographs. Tillaux and PLTA fracture, however, will be missed due to the superimposition of the fibula. Furthermore, as an intraarticular fracture of Tillaux fracture, it may be difficult to evaluate the actual amount of the displacement and the direction with the plain radiographs. Horn et al\[15\] compared the accuracy of CT and plain radiographs in evaluation of juvenile Tillaux fractures in cadaver specimens. They concluded that CT was more sensitive than plain radiographs in detecting fractures with more than 2 mm of displacement. Moreover, CT can reveal the true dimensions and displacement of these fragments. In present study, the diagnosis of Tillaux fracture in one and both of the avulsion of PLTA were missed in plain radiographs, however, identified on axial CT. We recommended that CT scanning will be extremely paramount to demonstrate the fracture clearly and be helpful to make decision in treatment for cases of high-energy ankle injury.

There was commonly significant edema of the soft tissue following high-energy injury and the wound infection and necrosis rates up to 33%\[16\]. Miller et al\[17\] recommended that surgery be delayed to seven to 14 days until the soft-tissue edema has decreased. Meanwhile, strategy of staged treatment for severe ankle injury has been reported in good to excellent outcomes in adults\[18\]. This may be a dilemma for pediatric ankle fractures due to open physis. Although Crawford\[19\] noted that Tillaux fracture could be reduced 5 weeks later, reduction for physeal fractures was recommended generally not to be performed after five to seven days to minimize the PPC\[3, 10\]. In our series, surgery were underwent in five cases with three to seven days between the injury and operation. Significant swelling was encountered in one case and the surgery was delayed until 3 weeks resulting in nonunion of MMF and Tillaux fracture.

Hanhisuanto et al\[20\] recommended that more than 2 mm displaced fractures be treated operatively for MMF. In our series, the initial displacement for Tillaux fracture was more greater(2-9.4 mm) than 2 mm due to the high-energy force, and all cases exception one were performed by open reduction and K-wires fixation. The result was comparable with the fixation of screws\[19,21\]. Our study showed that four cases
obtained bony union with closed reduction and K-wire and one nonunion because of no reduction or technique error. Hence, we found that it is of significant importance to fix MMF.

In five distal fibular fractures, three patients with TS were immobilized with plate and screws to restore and maintain the mortise. The widening of medial joint space and TS were reduced to normal in two cases with reduction of the fractures. SD was detected in one case on preoperative axial CT and persistent diastasis was confirmed postoperatively (Fig. 3). This may be the result of Tillaux fracture and MMF being not reduced and fixed.

There were rare reports with respect to the avulsion of PLTA in adolescence. In adult, treatment of posterior malleolus is determined by several factors, such as the size of fragment, the fracture gap, and the step-off of the joint surface [13,22]. Von Hooff [22] et al found when the posterior malleolar fracture fragments was more than 5% and the step-off more 1 mm, osteoarthritis occurred more frequently. Donken et al [23] reported a good long-term clinical and radiological result treated conservatively with closed reduction and cast. In present series, we found no displacement and no fixation was undergone for both cases.

One study of intra-articular physeal injury of the ankle by Caterini et al [24], with an average follow-up of 27 year, showed radiographic osteoarthritis signs in 11.8%. They found that the initial displacement and the quality of reduction were the main risk factors that determined the results. In our study, one child developed posttraumatic osteoarthritis due to the malreduction of Tillaux fracture and instability of the ankle. Furthermore, this case suffered from falling that may cause significant cartilage damage.

In conclusion, simultaneous Tillaux fracture and MMF in adolescents is rare and has not been previously reported. Diagnosis at the initial admission using plain radiographs are challenging, and CT is recommended. It is the recommendation of this study that ORIF can be efficacious for joint congruity.

**Abbreviations**

AITFL: anterior inferior tibiobular ligament

MMF: medial malleolar fracture

PPC: premature physeal closure

S-H: Salter-Harris epiphyseal injury type

H: Herscovici classification

AP: anteroposterior

CT: computed tomography

PLTA: posterolateral tibial aspect
Declarations

Ethics approval and consent to participate in present study was approved by the Ethics Committee of Children's Hospital of Soochow University. Written informed consent was acquired for all patients.

Consent for publication

Not applicable.

Availability of data and material

All data generated or analysed during this study are included in this manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding was provided.

Acknowledgements

We thank all of the patients involved in the study.

Authors' contributions

YZ contributed to the study design and is the corresponding author. QY and XW contributed to the study design, data analysis and interpretation, and manuscript draft. ZG, JD, FZ and JF contributed to the data collection and analysis. CY contributed to the data collection and analysis. WY contributed to the literature search and manuscript revision. All authors have read and approved the final manuscript.

References

1. Seel EH, Noble S, Clarke NM, Uglow MG. Outcome of distal tibial physeal injuries. J Pediatr Orthop B. 2011;20(4):242-8.
2. Spiegel PG, Cooperman DR, Laros GS. Epiphyseal fractures of the distal ends of the tibia and fibula. A retrospective study of two hundred and thirtyseven cases in children. J Bone Joint Surg Am. 1978;60(8):1046–50.

3. Cass JR, Peterson HA. Salter-Harris Type-IV injuries of the distal tibial epiphyseal growth plate, with emphasis on those involving the medial malleolus. J Bone Joint Surg Am. 1983;65(8):1059–70.

4. Cottalorda J, Béranger V, Louahem D, Camilleri JP, Launay F, Diméglio A, Bourelle S, Jouve JL, Bollini G. Salter-Harris Type III and IV medial malleolar fractures: growth arrest: is it a fate? A retrospective study of 48 cases with open reduction. J Pediatr Orthop. 2008;28(6):652-5.

5. Petratos DV, Kokkinakis M, Ballas EG, Anastasopoulos JN. Prognostic factors for premature growth plate arrest as a complication of the surgical treatment of fractures of the medial malleolus in children. Bone Joint J. 2013;95-B(3):419-423.

6. Herscovici D Jr, Scaduto JM, Infante A. Conservative treatment of isolated fractures of the medial malleolus. J Bone Joint Surg [Br]. 2007;89 B (1):89-93.

7. Gourineni P, Gupta A. Medial joint space widening of the ankle in displaced Tillaux and Triplane fractures in children. J Orthop Trauma. 2011;25(10):608-11.

8. Salter RB, Harris WR. Injuries involving the epiphyseal plate. J Bone Joint Surg Am. 1963;45:587–622.

9. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349-53.

10. Ali Al-Ashhab ME, Mahmoud Mohamed AA. Treatment for displaced Tillaux fractures in adolescent age group. Foot Ankle Surg. 2019;16.pii:S1268-7731(19)30054-2.

11. Kose O, Yuksel HY, Guler F, Ege T. Isolated adult Tillaux fracture associated with Volkmann fracture-a unique combination of injuries: report of two cases and review of the literature. J Foot Ankle Surg. 2016;55(5):1057-1062.

12. Boggs LR. Isolated posterior malleolar fractures. Am J Emerg Med.1986,4(4):334-6.

13. Ebraheim NA, Elgafy H, Padanilam T. Syndesmotic disruption in low fibular fractures associated with deltoid ligament injury. Clin Orthop Relat Res. 2003;(409):260-7.

14. Ebraheim NA, Weston JT, Ludwig T, Moral MZ, Carroll T, Liu J. The association between medial malleolar fracture geometry, injury mechanism, and syndesmotic disruption. Foot Ankle Surg. 2014,,20(4):276-80.

15. Horn BD, Crisci K, Krug M, Pizzutillo PD, MacEwen GD. Radiologic evaluation of juvenile Tillaux fractures of the distal tibia. J Pediatr Orthop. 2001,21(2):162-4.

16. Stannard JP, Robinson JT, Anderson ER, McGwin G Jr, Volgas DA, Alonso JE. Negative pressure wound therapy to treat hematomas and surgical incisions following high-energy trauma. J Trauma. 2006;60(6):1301-6.

17. Miller AG, Margules A, Raikin SM. Risk factors for wound complications after ankle fracture surgery. J Bone Joint Surg Am. 2012;21;94(22):2047-52.
18. Patterson MJ, Cole JD. Two-staged delayed open reduction and internal fixation of severe pilon fractures. J Orthop Trauma. 1999;13(2):85-91.

19. Crawford AH. Triplane and Tillaux fractures: is a 2 mm residual gap acceptable? J Pediatr Orthop. 2012;32(1):S69-73.

20. Hanhisuanto S, Kortekangas T, Pakarinen H, Flinkkilä T, Leskelä HV. The functional outcome and quality of life after treatment of isolated medial malleolar fractures. Foot Ankle Surg. 2017;23(4):225-9.

21. von Laer L. Classification, diagnosis, and treatment of transitional fractures of the distal part of the tibia. J Bone Joint Surg Am. 1985;67(5):687-98.

22. Drijfhout van Hooff CC, Verhage SM, Hoogendoorn JM. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. Foot Ankle Int. 2015;36(6):673-8.

23. Donken CC, Goorden AJ, Verhofstad MH, Edwards MJ, van Laarhoven CJ. The outcome at 20 years of conservatively treated ‘isolated’ posterior malleolar fractures of the ankle: a case series. J Bone Joint Surg Br. 2011;93(12):1621-5.

24. Caterini R, Farsetti P, Ippolito E. Long-term followup of physeal injury to the ankle. Foot Ankle. 1991;11(6):372-83.

Figures
Figure 1

(Case 2): A, AP radiograph showed Tillaux fracture, distal fibular fracture, and MMF associated with widening of the tibiofibular clear space and medial space of the ankle (black double arrow). B, Axial CT section showed 8mm displacement of Tillaux fragment and a normal incisura fibularis. C, Coronal CT scan showed widening of the medial clear space of the ankle, which indicates TS. D, AP plain radiograph obtained 12 months after treatment showed complete reduction of medial joint space immediately post operatively.
Figure 2

(Case 4): A, AP radiograph showed Tillaux fracture, distal fibular fracture, and MMF associated with widening of the tibiofibular clear space and medial space of the ankle. B, Lateral view showed a radiolucent zone consistent with a fracture at the posterior aspect of the tibia (arrows), but it was not clear because of superimposition of the fibula. C, Axial CT section showed 9.4mm displacement of Tillaux fragment, a normal incisura fibularis and avulsion of PLTA with intact medial cortex. D, AP plain radiograph obtained ten months after treatment showed complete reduction of medial joint space immediately post operatively. MMF was not fixed by the K-wire due to technique error.
Figure 3

(Case 5): A, AP radiograph showed Tillaux fracture, distal fibular fracture, and MMF associated with widening of the tibiofibular clear space and medial space of the ankle. B, Axial CT section showed 8.2mm displacement of Tillaux fragment, and SD. C, AP plain radiograph obtained 27 months after treatment of the initial fracture showed nonunion of the Tillaux fracture and MMF and persistent TS. D, Axial CT section confirmed the nonunion of the Tillaux fragment and the persistent diastasis of the distal tibiofibular joint.