Risk Factors and Surgical Sequelae of Physeal Arrest in Pediatric Salter-Harris III and IV Medial Malleolus Fractures

Owen S Roth, Apeksha Gupta, Tolu Adebayo, Mikhail Tretiakov

INTRODUCTION: Pediatric medial malleolus fractures pose a risk for physeal bar formation and growth disturbances. This study aimed to determine the rate of physeal bar formation following Salter-Harris (SH) III or IV medial malleolus fractures and identify patient, fracture, and management factors predictive of bar formation. A secondary objective was to evaluate the rate of additional surgeries required in the event of physeal bar formation.

METHODS: A retrospective review was performed of 161 patients (age<16) with isolated medial malleolus or bimalleolar fractures. Fifty-six skeletally immature patients (39% female) with SH III or IV medial malleolus fractures and ≥6 months radiographic follow-up met inclusion criteria. Demographics, injury mechanism, fracture management, and secondary surgeries were recorded. Radiographs were analyzed for fracture displacement, SH classification, coronal plane physeal involvement, anterior and lateral distal tibial angles, post-reduction displacement, and physeal bar formation. Wilcoxon rank sum tests assessed statistical significance (α<0.05).

RESULTS: Thirty-five isolated medial malleolus and 21 bimalleolar ankle fractures were identified (SH III=40, SH IV=16). Initial treatment was operative in 34 patients (60.7%), with greater fracture displacement (4.9mm vs. 2.4mm) and coronal plane physeal involvement (21.5% vs. 16.4%) being significant predictors of surgical management (P <0.05). Physeal bars developed in 17 patients (30.4%), with a mean diagnosis time of 8.4 months. Patients with bar formation also presented with significantly greater fracture displacement (5.4 mm vs. 3.3 mm) and coronal plane physeal involvement (23.6% vs. 17.8%) (P <0.05). No difference in bar formation rates was observed among other patient or fracture characteristics. Eight of 17 physeal bar patients (47%) required at least one secondary surgery, including bar resection (n=4), epiphysiodesis (n=7), and/or osteotomies (n=3).

DISCUSSION AND CONCLUSION: Pediatric periphyseal medial malleolus fractures carry high risk for physeal bar formation. Greater fracture displacement and coronal plane physeal involvement were significant predictors of initial surgical management and bar formation. Close radiographic monitoring of these high-risk fractures for at least one year following injury and attentive patient counseling on risk of secondary surgery is recommended for timely identification and intervention.

Table 1: Summary of Patient and Treatment Characteristics

Variable	N=56
Age at injury (years), Mean ± SD	11.2 ± 2.4
Sex	
Male	34 (60.7%)
Female	22 (39.3%)
Weight (kg), Mean ± SD	43.8 ± 14.0
Mechanism of Injury	
Sports	17 (30.4%)
Falls	16 (28.6%)
Trampolines	16 (28.6%)
Blunt trauma	7 (12.5%)
Fracture location	
Isolated Medial Malleolus	35 (62.5%)
Bimalleolar	21 (37.5%)
Salter-Harris Classification	
III	40 (71.4%)
IV	16 (28.6%)
Initial operative treatment	34 (60.7%)
Fixation type	
Wires	4 (11.7%)
Screws Only	29 (85.3%)
Plate and Screws	1 (2.9%)
Initial non-operative treatment	22 (39.3%)
Hardware removal	27 (79.4%)

Table 2: Factors Associated with Operative Versus Non-Operative Initial Treatment

Variable	Operative (n=34)	Non-operative (n=22)	P-value
Sex (male)	26 (76.5%)	8 (36.4%)	—
Weight (kg), Mean ± SD	45.3 ± 14.5	41.5 ± 13.3	0.4485
Age at injury (years)	11.7 ± 2.1	10.4 ± 2.8	0.1389
Initial displacement (mm)	4.9 ± 5.4	2.4 ± 3.0	**0.0002**
Coronal plane physeal involvement (%)	21.5 ± 7.7	16.4 ± 8.1	**0.0254**
ADTA (°)	83.8 ± 2.0	83.5 ± 1.8	0.7929
LDTA (°)	89.6 ± 2.3	89.7 ± 2.0	0.9696

ADTA, Anterior Distal Tibia Angle; LDTA, Lateral Distal Tibia Angle

Table 3: Prediction of Physeal Bar Formation Based on Demographic Variables and Initial Treatment

Variable	Physeal bar present (n=17)	No physeal bar present (n=39)	P-value
Sex (n)			0.4317
Male	9	25	
Female	8	14	
Weight (kg), Mean ± SD	48.4 ± 16.9	41.2 ± 4.3	0.1957
Age at injury (years)	11.3 ± 2.5	11.0 ± 2.4	0.8039
Time from injury to surgery (days)	4.6 ± 4.6	6.2 ± 4.4	0.1899
Initial operative treatment (n)	14	20	**0.0385**
Mechanism of injury			—
Sports	3 (17.6%)	14 (35.9%)	
Falls	4 (23.5%)	12 (30.8%)	
Trampolines	8 (47.1%)	8 (20.5%)	
Blunt trauma	2 (11.8%)	5 (12.8%)	

Table 4: Prediction of Physeal Bar Formation Based on Radiographic Variables

Variable	Physeal bar present (n=17)	No physeal bar present (n=39)	P-value
Initial displacement (mm), Mean ± SD	5.4 ± 5.5	3.3 ± 4.3	**0.0063**
Coronal plane physeal involvement (%)	23.6 ± 9.3	17.7 ± 7.1	**0.0223**
ADTA (°)	83.6 ± 2.4	83.7 ± 1.7	0.4951
LDTA (°)	90.1 ± 2.2	89.4 ± 2.2	0.2246
Reduction (mm)	1.0 ± 1.0	0.91 ± 0.72	0.6478
Salter-Harris Classification			0.1050
III	10	30	
IV	7	9	

ADTA, Anterior Distal Tibia Angle, LDTA, Lateral Distal Tibia Angle

Table 5: Summary of Patients Who Underwent Secondary Surgeries for Management of Physeal Bar Formation

Patient #	Age[*]	Time to bar[†]	Indication	Time to procedure[†]	Procedure(s)[‡]
1	7.3	21	Deformity	28	Distal tibia epiphysiodesis; tibia osteotomy; fibula osteotomy
				38	Repeat distal tibia and fibula epiphysiodesis
2	5.5	2	Deformity	3	Physeal bar resection
				61	Repeat bar resection; tibia osteotomy; fibula osteotomy
				86	Distal tibia and fibula epiphysiodesis; tibia osteotomy
3	13.5	7	Deformity	7	Distal tibia epiphysiodesis
4	9.0	9	Deformity	10	Physeal bar resection
5	13.4	4	Pain	5	Distal tibia and fibula epiphysiodesis
6	11.6	12	Deformity	13	Distal tibia and fibula epiphysiodesis
7	14.2	6	Deformity	10	Physeal bar resection
8	9.6	12	Deformity	13	Distal tibia and fibula epiphysiodesis

[*]At initial injury.
[†]Values represent months from injury.
[‡]Multiple procedures for individual patients are listed in separate rows.