



Post infective physeal bar sequelae around knee: Natural history and coronal plane deformities[☆]



Anil Agarwal^{*}, Ravi Jethwa

Department of Paediatric Orthopaedics, Chacha Nehru Bal Chikitsalaya, Geeta Colony, Delhi, 110031, India

ARTICLE INFO

Article history:

Received 5 September 2022

Received in revised form

10 February 2023

Accepted 28 May 2023

Available online 3 June 2023

Keywords:

Knee

Physeal bar

Septic arthritis

Osteomyelitis

ABSTRACT

Background: and methodology: The presented retrospective study is a report of 17 children (18 limbs) with post infective physeal bars around the knee. Minimum 2 years follow up post sepsis follow up was available.

Observations: The mean follow up post infection was 6.9 years. The bar formation manifested mean 22.6 months post sepsis. The angular deformity progressed at the mean monthly rate of 0.84, 0.1, 0.26° for peripheral, central and extensive bars respectively. Peripheral bars underwent early intervention. Balancing of physeal growth using contralateral '8' plate was useful for partial bars. For extensive bars and older patients, complete epiphyseodesis and limb length equalization was used. Articular abnormalities (cupping, flattening, small epiphysis) were associated in 80% bars. Neonatal infections were often multifocal and had articular abnormalities.

Conclusions: The 3 bar types presented with different characteristics. Peripheral bars produced most angular deformities and required early intervention. Articular abnormalities were associated with physeal bars in large number of patients especially those with neonatal infections. Overall unhealthy physis beside bar, delayed manifestations, and limb length discrepancy should be accounted for while planning treatment.

© 2023 Delhi Orthopedic Association. All rights reserved.

1. Introduction

Knee joint is one of the most common sites of hematogenous osteoarticular infection in children.¹ The infection can affect the physis in multiple ways.² The physis can be invaded by bacteria and host inflammatory cells following widespread involvement of the joint or metaphyseal bone. The child may also suffer ischemic changes of the physeal vasculature due to septic shock, pressure tamponade resulting from intraarticular/subperiosteal abscess or associated vasculitis.^{1,2} The affection of physis may be obvious soon after the infection or may be delayed for several years.³ It is commonly believed that the late affection of physis seen in some patients is probably because of ossification of fibrous scar tissue remaining in the growth plate.³

The characteristics of post infective physeal bars around the

knee in children are not completely known due to limited data on the subject.²⁻⁶ The effect on limbs is known to be significant when the physeal bar follows a neonatal event.³ Gross angular deformities, limb length discrepancies and articular irregularities have been described. The sequelae are particularly taxing to treat because of unpredictable surgical results following bar resection. In some patients, up to six osteotomies during the growth period may be required.³

We present our experience of managing 17 children (18 limbs) with post infective physeal bars around knee over a span of 13 years. The purpose was to get an insight into different types of bars, the coronal plane deformities caused and the effect of surgical intervention/non intervention for the sequelae. The mean follow up post infection for the included patients was 6.9 years.

2. Methods

The retrospective study was carried out at a tertiary care pediatric centre located in suburb of a lower middle income country. A radiological chart review of patients with post infective physeal bars around knee region (treated septic arthritis of knee joint or/

[☆] Not presented anywhere.

^{*} Corresponding author. Department of Pediatric Orthopedics, Chacha Nehru Bal Chikitsalaya, Geeta Colony, Delhi, 110031, India.

E-mail addresses: anilrachna@gmail.com (A. Agarwal), ravibj08@gmail.com (R. Jethwa).

and osteomyelitis of distal femur and proximal tibia) was carried out from January 2009 to December 2021. The additional inclusion criteria for the study was availability of minimum 2 years follow-up post sepsis (Tables 1–3). Traumatic and tubercular physeal bars were excluded.

Primary radiographic evaluation and follow up was based on plain anteroposterior and lateral X-rays although for surgically intervened patients, computed tomography (CT) imaging was also available. To facilitate bar quantification in plain radiographs, we used a combination of Peterson classification of physeal arrest⁷ and Stevens' knee zoning.⁸ Although described for transverse width of the physis, the zoning was considered to represent total physeal area for the purpose of bar's impact in coronal plane. Each zone (+2 to -2) thus approximately represented 25% area of the physis. The partial physeal bars were those which were limited to one knee zone (+2, +1, -1 or -2) and accordingly peripheral (in zone +2 or -2) or central (in zone +1 or -1). A bar spanning more than one zone represented an involvement of >25% physis and therefore considered an extensive physeal bar.

The coronal plane angular deformity was quantified using anatomical lateral distal femoral angle (aLDFA) or medial proximal tibial angle (aMPTA) as the case may be. Corresponding values from the opposite unaffected limb were taken as reference for comparison. The rate of progression of deformity was calculated by dividing the total deformity by duration since infection and prior to any intervention.

The timing of appearance of bar post sepsis was quantified from limbs where serial radiographs since infection were available (distal femur n = 3, proximal tibia n = 5). Angular deformity prior to any surgical intervention, the interventions performed, final deformity and limb length discrepancy were documented.

3. Observations

There were 10 boys and 7 girls with 18 involved limbs. Six patients were primarily managed at our institution immediately following infection (Tables 1–3). Right limb was involved in 12 and left in 6. Bar was seen in distal femur in 10 and proximal tibia in 8. The bar formation manifested at mean period of 22.6 months (12–36 months) post infection. In distal femur, it was observed at a mean of 23 months and for tibial cases, 22.4 months. The mean follow up post infection was 6.9 years (2–14 years).

3.1. Partial physeal bars

A. The peripheral physeal bars

Seen in 3 patients (femur 1: tibia 2) (Table 1). For this group, the bar was noticed at a mean 30 months post infection. The angular deformity progressed at a mean rate of 0.84°/month since infection and prior to any intervention. The mean age for intervention in this group was 4 years. In 2 of these patients, bar resection and contralateral hemiepiphysodesis using '8' plate was offered. In one patient, the method completely corrected the angular deformity. Following removal of '8' plate at age 8 years, the deformity recurred rapidly due to an unhealthy physis [reduced/aborted growth potential of the physis] (Fig. 1). In the other patient, the contralateral hemiepiphysodesis kept the angular deformity in check for 6 years. At 10 years, larger areas of physis arrest were obvious. This patient later required a closing wedge distal femoral osteotomy and complete arrest of physis. Epiphysodesis of distal femur of opposite limb was added for correction of limb length discrepancy.

The mean follow up post infection for peripheral bar group was 8.2 years. The mean angular deformity in the intervened group at

Table 1
Partial physeal bars: peripheral.

S.no.	Age at infection (months)	Age first presented (months)	Femur/ tibia	Sepsis treatment	Age at intervention (any) (years)	Age at intervention (if deformity ^a) (degrees)	Preintervention deformity ^a (degrees)	Primary intervention	Follow up post infection (years)	Deformity at final follow up ^a	Shortening (cm)	Articular abnormality	Remarks
1.	12	23	Right tibia	AB	4	40	40	BE + HE contralateral side	10.5	49	12	F	Concomitant involvement right distal tibia
2.	24	36	Left femur	AB	4	27.8	27.8	BE + HE contralateral side	11	0	1.5	–	Permanent epiphysodesis + closing wedge osteotomy left distal femur + right distal femur epiphysodesis at age 10 years
3.	1	1	Right tibia	I and D + AB	–	–	–	–	3	7.9	2	F	Neonatal infection

BE-bar excision; HE-hemiepiphysodesis; AB-antibiotics; I and D-incision and drainage; F- flattening.
^a Deformity as compared to opposite unaffected limb [aLDFA (femur) or aMPTA (tibia)].

Table 2
Partial physal bars: central.

S. no.	Age at infection (months)	Age first presented (months)	Femur/ tibia	Sepsis treatment	Age at intervention (if any) (years)	Preintervention deformity ^a (degrees)	Primary intervention	Follow up post infection (years)	Deformity at final follow up ^a	Shortening (cm)	Articular abnormality	Remarks
1.	0.5	1	Right tibia	AB	–	–	–	2	1.8	0	C	Neonatal infection
2.	3	3	Right tibia	Arthrotomy + AB	9	8.5	Lateral closing proximal tibial osteotomy + permanent epiphyseodesis + left proximal tibial epiphyseodesis	13	6	2	–	
3.	24	120	Right tibia	AB	10	10.2	BE + medial open wedge tibial osteotomy + HE contralateral side	11	1.8	3	–	
4.	0.5	0.5	Left tibia	Multiple aspirations + AB	–	–	–	3	2	2	Small rounded epiphysis	Neonatal infection; concomitant involvement right elbow
5.	8	14	Right femur	I and D + AB	–	–	–	3	3.7	2	C	
6.	24	34	Left femur	I and D + AB	3.3	9	BE + HE contralateral side	3	11.7	2	C	No effect of bar resection till latest follow up
7.	0.5	36	Right femur	I and D + AB	–	–	–	3	1.4	2.5	F	Neonatal infection; concomitant involvement right hip and knee

BE-bar excision; HE-hemiepiphyseodesis; AB-antibiotics; I and D-incision and drainage; F- flattening; C-cupping.

^a Deformity as compared to opposite unaffected limb [aLDFA (femur) or aMPTA (tibia)].

3

Table 3
Physal bar extensive.

S. no.	Age at infection (months)	Age first presented (months)	Femur/ tibia	Sepsis treatment	Age at intervention (if any) (years)	Preintervention deformity ^a (degrees)	Primary intervention	Follow up post infection (years)	Deformity at final follow up ^a	Shortening (cm)	Articular abnormality	Remarks
1.	48	120	Right tibia	I and D + AB	10	28.7	Medial opening osteotomy proximal tibia + left proximal tibial epiphyseodesis	10	0	0	F	Repeat medial opening osteotomy + permanent epiphyseodesis right proximal tibia at age 12 years
2.	60	120	Left femur	AB	10	23.1	Lateral closing osteotomy distal femur + right distal femur and proximal tibia epiphyseodesis	10	47.8	7	C	–
3.	0.5 ^b	84	Both femur	AB	7	Right 0.7 Left 10.5	Extension osteotomy right distal femur	19	Right 20 Left 16.9	Not calculated	Right: C Left: C	Neonatal infection; concomitant involvement both hips, left ankle and shoulder
4.	1	1	Left femur	AB	–	–	–	2.5	25.4	5	C	Neonatal infection; concomitant involvement both hips
5.	60	60	Right femur	I and D + AB	5	10	Sequestrectomy	3	0	2	F	
6.	36	120	Right tibia	AB	10	29.4	Medial opening osteotomy proximal tibia	9	1.7	0	–	
7.	0.5	60	Right Femur	AB	–	–	–	5	10	5	C	Neonatal infection; concomitant involvement right elbow

BE-bar excision; HE-hemiepiphyseodesis; AB-antibiotics; I and D-incision and drainage; F- flattening; C-cupping.

^a Deformity as compared to opposite unaffected limb [aLDFA (femur) or aMPTA (tibia)].^b Reference taken as 90° for angular deformity.



Fig. 1. Peripheral physeal bar: A. This 12 months child suffered extensive diaphyseal osteomyelitis of tibia right side. Both proximal and distal tibial physis were affected B. A physeal bar was obvious about 36 months post infection C. At age 4 years, the bar was excised and physis balanced with application of contralateral '8' plate D. The plate was removed at age 8 years following correction of angular deformity E. Follow up at age 11.5 years. The deformity recurred rapidly due to an unhealthy physis.

final follow up was 24.5° and limb length discrepancy 6.8 cm. The third non intervened patient aged 3 years had an angular deformity of 7.9° tibia vara and limb length discrepancy of 2 cm.

B. The central physeal bars

Seen in 7 patients (femur 3: tibia 4) (Table 2) (Fig. 2). The bar was noticed at a mean 19.4 months post infection in plain radiographs. The angular deformity progressed at a mean rate of 0.1°/month since infection and prior to any intervention. The progression of angular deformity was more pronounced for a femoral physeal bar (femur 0.15°/month: tibia 0.09° per month). The mean age for intervention in this group (n = 3) was 7.4 years. Correction of

residual angular deformity using osteotomy combined with complete arrest of the affected physis was attempted for 1 older patient. In two younger patients, physeal bar excision combined with contralateral hemiepiphysiodesis using '8' plates was performed. For one patient, the procedure balanced the proximal tibial growth. In other patient, the physeal resection had no appreciable effect in the available 2 years follow up. At final follow up (mean 9 years post infection), the mean residual angular deformity and limb length discrepancy for the intervened limbs was 6.5° and 2.3 cm respectively. The pathology was still under observation in 4 patients with angular deformity less than 5° and limb length discrepancy under 2.5 cm.

3.2. The extensive physeal bars

Seen in 7 patients (8 limbs) (femur 6: tibia 2) (Table 3) (Figs. 3 and 4). The bar was noticed at a mean 24 months post infection in plain radiographs. For the extensive bars, the angular deformity progressed at mean rate of 0.26°/month since infection and prior to any intervention. The mean age for intervention (n = 5) in this group was 8.5 years. Three patients were operated for correction of angular deformity. Temporary epiphysiodesis of the opposite limb was added in two patients. One patient underwent extension osteotomy of the knee region. Another patient had recurrent infection and required sequestrectomy procedure. A repeat osteotomy was required in one patient due to recurrence of angular deformity.

The mean follow up post infection was 8.4 years. The mean angular deformity in the intervened limbs at final follow up was 13.9° and limb length discrepancy 2.3 cm. For non intervened limbs, the values were 17.4° and 5 cm respectively.

Additional observations: Articular abnormalities were obvious in most limbs (78%; 14/18 knees) (Figs. 3 and 4). The classical described articular irregularity (cupping/tenting/forking) was present only in 8 knees.² Cupping was found in 3 central and 5 extensive bars. One knee had small rounded epiphysis. Five patients (5 limbs) presented with flattening of articular surface rather than cupping (Fig. 4).

Seven (8 limbs) out 17 patients had neonatal infections (Figs. 2 and 3). Five out of seven patients had additional involvement of other joints. In three limbs, the bar was extensive, 3 had central and one had eccentric bar. In all of these patients, the bar was associated

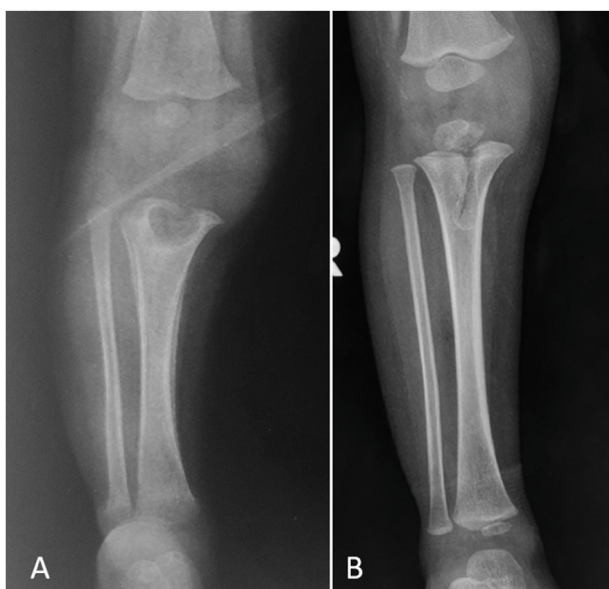


Fig. 2. Central physeal bar: This neonate had a history of critical care admission and intravenous antibiotic administration due to sepsis A. Two months following admission, radiographs revealed evidence of chronic osteomyelitis and cyst formation in proximal tibia. Epiphysis was not visible at this stage B. At 2 years follow up post infection, a central physeal bar is obvious. Mild cupping of the epiphysis is also evidenced.

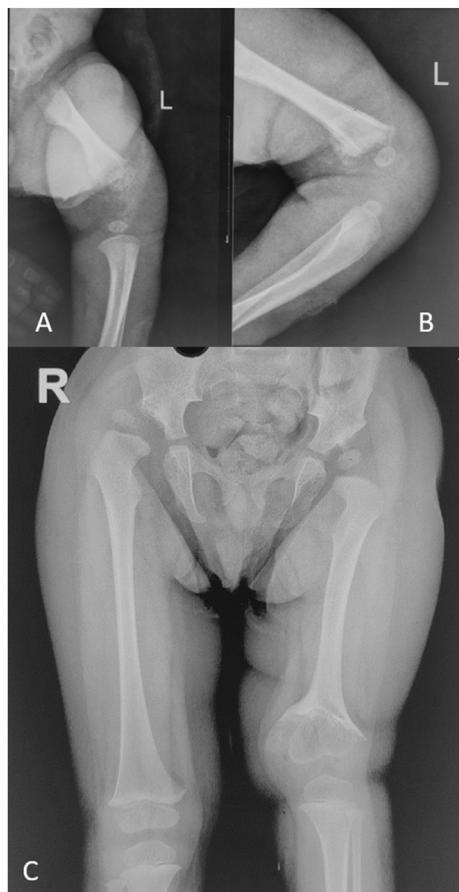


Fig. 3. Extensive physeal bar: A. Neonatal infection involving left hip, femur, and knee B. Follow up at 2.5 years. The missed infection of right hip is obvious in form of post septic dislocation of hip. The left hip is dysplastic and there is extensive bar formation in distal femur left side. Articular abnormality and cupping is present.

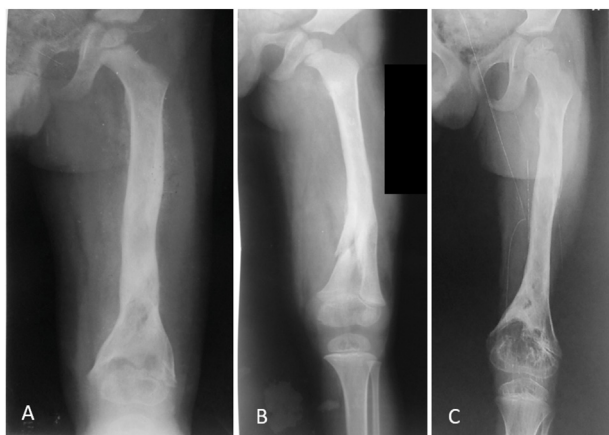


Fig. 4. Extensive physeal bar: A. Five year old child with osteomyelitis right femur treated with drainage and antibiotics B. The child required removal of sequestrum C. At 3 years follow up, the extensive bar formation and flattening of the distal femoral articular surface is obvious.

with some form of articular abnormality. Neonatal infection was more commonly associated with cupping (5/8 knees). Excluding the patient with bilateral involvement, the limb length discrepancy for neonatal group was mean 2.8 cm (range, 0–5 cm) at a mean follow up of 3.1 years (range, 2–5 years).

4. Discussion

4.1. Principal findings

The post infective physeal bars around knee have potential to produce marked angular deformities or limb length discrepancies. They can also significantly disturb the articular surface. For our series, although the precise timing of bar appearance remained unpredictable, it was obvious approximate 23 months post infection. In some patients, the extent of bar widened on longer follow up (patient 2, peripheral physeal bar). Being closer to midline, the central and extensive bar pathologies produced lesser angular deformities (peripheral = $0.84^\circ/\text{month}$; central = $0.1^\circ/\text{month}$; extensive $0.26^\circ/\text{month}$).

Articular abnormalities were found in large number of limbs affected with bar formation (78%). Tenting/cupping/forking as variously known was observed when growth arrest produced significant changes in the adjoining condyles. It was seen more commonly following neonatal infections. Besides tenting, flattening of articular surfaces was also observed.

Of the 3 bar varieties, those with peripheral bars were brought to attention much earlier probably because of significant angular deformities they produced. This variety was therefore intervened quite early (peripheral 4 years < central 7.8 years < extensive 8.5 years). Judicious use of bar excision combined with balancing contralateral hemiepiphyodesis was found useful in select patients with peripheral bars. The results however remained unpredictable in some patients. A rapid recurrence of the angular deformity was observed following removal of balancing hemiepiphyodesis in one patient indicating an overall diseased physis. The central bars produced lesser degrees of angular deformities and for several young children, the primary treatment of bar excision/deformity correction was combined with compensations for limb length discrepancy. The extensive bars were treated by corrective osteotomies. For limb length discrepancies, growth modulation of opposite limb was performed. Late manifestation of sequelae, limb length discrepancy or recurrences after interventions necessitated repeat procedures in some patients.

4.2. Review of literature

Epidemiological studies of paediatric pyogenic musculoskeletal infections have revealed osteomyelitis as the most common pyogenic musculoskeletal infection.⁹ Tibia and femur are the commonest bones involved in osteomyelitis and knee and hip joints in septic arthritis. Thus, knee remains prone to affection in various types of musculoskeletal infection. Yet, there isn't much literature on post infective physeal bar around knee region in children.^{2–6} Langenskiöld mentioned its occurrence in 4 out of 7 patients with osteomyelitis of the femoral condyles.³ The physeal closures appeared after a variable period of 6–12 years. He recognized that partial closure of the physis could result in rapid onset deformity. The recurring deformity required up to 6 osteotomies in his series.³ He cautioned on the disabling limb length discrepancy the post neonatal physeal closures can produce and the need for timely interventions. When the bridge was large (not quantified), he recommended against their resection. Strong et al., in 1994, pointed that central growth arrest was more commonly associated with cupping.⁴ Peterson described that the post infective bar excisions may have inferior surgical results than traumatic bars.²

In our series, the physeal bars were appreciated within a span of 2 years following infection. The partial bars did predispose to higher rate of angular deformations. The 'balancing' of physis (bar excision + contralateral hemiepiphyodesis) however limited the number of osteotomies required in partial physeal bars. The

infective process may produce changes in overall physis and this may be the reason for inferior results noted in some patients following post infective bar resections. Further, the interventions were varied and did not always involve bar excision. Articular abnormalities were seen in approximately 80% limbs and most (63%) were associated with extensive bar. Other varieties of articular abnormalities other than cupping were also seen our series.

4.3. Clinical implications

All the post infective physeal bars in our series were seen in patients who had associated metaphyseal osteomyelitis of distal femur/proximal tibia. Therefore, we believe that metaphyseal osteomyelitis predisposed to bar formations more commonly than septic arthritis. The young age at which the physeal bars manifested especially the peripheral ones posed significant management challenges. The 'balancing' procedure was attempted in some patients. The normal growth potential of the physis may not be restored post bar excision. Prolonged use of '8' plate was therefore justified in several of these patients. Timely temporary epiphyseodesis of opposite limb may prevent gross limb length discrepancy associated with this entity. For patients nearing skeletal maturity, permanent epiphyseodesis may be the only option for the diseased physis. Neonatal infections predisposed to articular abnormalities and may be prone for early degenerative changes.

4.4. Limitations

It was a hospital-based retrospective radiological chart review of 17 patients. The disease is sufficiently rare to warrant description for lesser numbers. The age of the patients at presentation, type of initial management, conservative versus operative intervention, and final follow-up duration differed. The timing of excision of physeal bar varied based on several factors e.g. age at presentation, bar dimensions and location, coronal plane deformity at time of presentation, and in some patients, after serial monitoring for rate of progression of deformity. Because of limited number of patients and above mentioned heterogeneity in each group, derivation of meaningful statistical relationships between bar size, impact of intervention and overall outcome was not possible. The study is therefore presented as descriptive study. The various prognostic factors related to disease such as prematurity, delay in institution of primary treatment, organism virulence etc. was beyond our preview. Most children were not yet skeletally mature and the final outcome might alter further due to growing skeleton, late effects of physeal insult, or additional surgical interventions. We used plain radiographs for imaging evaluation, which although have many drawbacks but still remains the most viable method for follow-up in our set up.

4.5. Strengths

We are unaware of any series which have quantitatively assessed the post septic physeal bar sequelae of knee region in

children. The series also described the effect of interventions in these patients. Some included children had long term follow-up from the primary septic episode till skeletal maturity.

5. Conclusions

Of the three physeal bar types, the peripheral ones produced most angular deformities. Overall, the whole physis may be unhealthy resulting in unpredictable results post excision or late deterioration of achieved corrections. In some patients, the complete effect of sepsis on physis was delayed and was seen several years later. 'Balancing' procedure using '8' plate contralateral to excised bar may be utilized when bar size is limited. Limb length discrepancy remained a major manifestation in all types of physeal bars. Articular abnormalities were found associated with physeal bars in large number of patients. The neonatal infection particularly predisposed to joint irregularities. Recurrences of deformities may necessitate repeat interventions and long term supervised follow up in these children.

Contribution

Anil Agarwal: Contribution: study design, and manuscript preparation, Ravi Jethwa: Contribution: data collection, analysis and manuscript preparation.

Financial conflicts

Nil.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Agarwal A, Aggarwal AN. Acute hematogenous osteomyelitis. In: Agarwal A, Aggarwal AN, eds. *Pediatric Osteoarticular Infections*. Delhi: Jaypee; 2014:93–106.
2. Peterson HA. *Physeal Injury Other than Fracture*. Heidelberg Dordrecht London New York: Springer; 2012.
3. Langenskiöld A. Growth disturbance after osteomyelitis of femoral condyles in infants. *Acta Orthop Scand*. 1984;55:1–13.
4. Strong M, Lejman T, Michno P, Hayman M. Sequelae from septic arthritis of the knee during the first two years of life. *J Pediatr Orthop*. 1994;14:745–751.
5. Hayes M, Andronikou S, Mackenzie C, du Plessis J, George R, Theron S. *Post-infective Physeal Bars – MRI Features and Choice of Management*. SA Journal of Radiology; 2007. Available at: <https://www.ajol.info/index.php/sajr/article/view/34498/6422>.
6. Roberts PH. Disturbed epiphysal growth at the knee after osteomyelitis in infancy. *J Bone Joint Surg Br*. 1970;52:692–703.
7. Peterson HA. *Epiphyseal Growth Plate Fractures*. Berlin Heidelberg: Springer-Verlag; 2007.
8. Stevens PM, MacWilliams B, Mohr RA. Gait analysis of stapling for genu valgum. *J Pediatr Orthop*. 2004;24:70–74.
9. Ahmad S, Barik S, Mishra D, Omar BJ, Bhatia M, Singh V. Epidemiology of paediatric pyogenic musculoskeletal infections in a developing country. *Sudan J Paediatr*. 2022;22:54–60.