REVIEW ARTICLE

Fractures of the patella in children

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ABSTRACT

Introduction: patellar fractures in children are infrequent and have several forms of presentation characteristic of the immature skeleton, as well as several treatment modalities.
Objective: to update and provide information on patellar fractures in children.
Methods: the search and analysis of the information was carried out in a period of 61 days (April 1 to May 31, 2022) and the following words were used: patellar fractures and Children, fractures of the patella and pediatrics and knee trauma. Based on the information obtained, a bibliographic review of a total of 192 articles published in the PubMed, Hinari, SciELO and Medline databases was carried out using the search manager and the EndNote reference manager; 37 selected citations were used to carry out the review, 36 from the last five years.
Development: reference is made to the characteristics of the patellar ossification center and vascularization. The mechanisms of production related to the incidence and specific features are mentioned. The most commonly used classification according to type and characteristics is presented. Treatment modalities are presented according to the type of lesion and surgical intervention criteria. Regarding complications, the most reported in the literature are described.
Conclusions: patellar fractures in children have very specific characteristics, for which it is necessary to know the anatomy of the immature skeleton, the mechanisms of production, the classifications and the types of treatments available for these patients.
Key words: fracture of the patella; fractures of the knee; knee trauma; fractures in the child

RESUMEN

Introducción: las fracturas de la rótula en el niño son infrecuentes y tienen varias formas de presentación propias del esqueleto inmaduro, así como varias modalidades de tratamiento.
Objetivo: actualizar y brindar información sobre las fracturas de la rótula en el niño.

Métodos: la búsqueda y el análisis de la información se realizó en un período de 61 días (primero de abril al 31 de mayo de 2022) y se emplearon las siguientes palabras: patellar fractures and Children, fractures of the patella and pediatrics y knee trauma. A partir de la información obtenida se realizó una revisión bibliográfica de un total de 192 artículos publicados en las bases de datos PubMed, Hinari, SciELO y Medline mediante el gestor de búsqueda y el administrador de referencias EndNote; se utilizaron 37 citas seleccionadas para realizar la revisión, 36 de los últimos cinco años.
Desarrollo: se hace referencia a las características del centro de osificación de la rótula y la vascularización. Se mencionan los mecanismos de producción relacionados con la incidencia y los rasgos específicos. Se expone la clasificación más empleada según el tipo y las características. Las modalidades de tratamiento son expuestas según el tipo de lesión y los criterios de intervención quirúrgica. Con relación a las complicaciones se describen las más informadas en la literatura.
Conclusiones: las fracturas de la rótula en el niño tienen características muy específicas, para lo que resulta necesario el conocimiento de la anatomía del esqueleto inmaduro, los mecanismos de producción, las clasificaciones y los tipos de tratamientos disponibles para estos enfermos.
Palabras clave: fractura de la rótula; fracturas de la rodilla; traumas de la rodilla; fracturas en el niño

INTRODUCTION

Fractures of the patella in children are infrequent traumatic injuries and represent less than 1% of all fractures and are usually seen in patients under 16 years of age. Most occur by 12 years of age, are more frequent in children and 80% are due to sports trauma and traffic accidents. Open fractures occur in only one third of patients and 13% are associated with fractures of the femur or tibia.[1]

The mechanism of production in these injuries can be both direct and indirect and can show various configurations.[2,3]

The clinical picture is related to the intensity and mechanism of production and there is a history of a well-defined trauma followed by pain, swelling and functional impotence of the joint. It is frequent to detect an increase in local temperature related to the presence of hemarthrosis.[4,5,6]

Imaging studies are of great help in the diagnosis, the most used is the simple radiography in anteroposterior, lateral and axial projections but, sometimes, due to the complexity of this lesion, magnetic resonance imaging and computerized axial tomography are necessary.[7,8,9]

Treatment depends on the type of lesion and can be conservative or surgical, in the latter variety the arthroscopic route offers additional diagnostic and therapeutic advantages.[10,11]

Due to the importance of this topic in pediatric traumatology and the scarce information available on this subject in the national literature, a review of this disease was carried out with the main objective of updating on patella fractures in children.

METHODS

The search and analysis of the information was carried out over a period of 61 days (April 1st to May 31st, 2022) and the following keywords were used: patellar fractures and Children, fractures of the patella and pediatrics and knee trauma. To focus the search, the Boolean operators OR or AND were used as appropriate. Based on the information obtained, a bibliographic review of a total of 192 articles published in the databases PubMed [https://pubmed.ncbi.nlm.nih.gov/], Hinari [https://www.who.int/hinari/es/], SciELO [https://scielo.org/es/] and Medline [https://medlineplus.gov/spanish/] was carried out using the search manager and reference manager EndNote, of which 37 selected citations were used to carry out the review, 36 from the last five years.
Review Articles, Original Articles and Case Presentations were considered. Animal research was excluded.

DEVELOPMENT

The ossification of the patella begins at the age of five to six years and ends at 18 years. This ossification is central and the pattern is similar to that of a secondary ossification nucleus. The peripheral chondro-osseous transformation is often irregular and may present small accessory foci of ossification which are, from the age of 12 years, progressively incorporated into the main ossification center. When this does not occur, the so-called multipartite or bipartite patellae appear.[12,13]
In relation to the vascularization of the patella, it comes from the peripatellar arterial circle as a result of anastomoses from six main sources (lateral and medial superior geniculate arteries, lateral and medial inferior geniculate arteries, recurrent anterior tibial artery and supreme geniculate artery). The intraosseous arteries that depart from the aforementioned circle are grouped into two main systems: the first one enters the middle third of the anterior surface and the second one enters the inferior pole of the patella, behind the patellar ligament. This vascular organization can vary and, occasionally, a large part of the patella in its inferior third is vascularized by a branch of the popliteal artery. This vascular pattern explains the ischemic changes after fractures, whether or not they are treated conservatively.[14,15,16]
The mechanism of production of patellar fractures in children can be direct or indirect (Table 1).[17,18,19]
In order to determine the type of fracture and to be able to classify patellar fractures, radiographic views in anteroposterior projections, lateral projections in 30 degrees of knee flexion and axial projections are needed to detect osteochondral lesions. Other useful tests are computed axial tomography, magnetic resonance imaging and bone scintigraphy. Imaging examinations of the affected knee should be compared with the contralateral joint.[20,21]

Table 1. Production mechanism, incidence and characteristics

Mechanism	Incidence	Characteristics
Direct	80%	Direct trauma in automobile accidents or sports with the knee in extension or when falling with the joint in flexion. In this modality, open fractures and associated ipsilateral fractures such as those of the femur and tibia are more frequent.
Indirect	20%	It is caused by chronic overloads (stress) or acute (associated with dislocation of the patella).

The classifications of patellar fractures in children are based on their mechanism of production, communication with the exterior and displacement, among others; the authors propose the one described by Cahuzac J,[22] from France (Table 2).

Table 2. Classification based on the type of patellar fracture in the child according to Cahuzac J[22]

Type	Features
Complete fractures of the primary ossification center	At the same time, they are divided into: – Transversas (common pattern) – Longitudinal – Conminutive (frequent and usually displaced).
Peripheral avulsion fractures	They may be located in any peripheral segment of the patella and the avulsed fragment may be cartilaginous in its entirety or include a small layer of subchondral bone, may be: – Avulsion of the upper pole (rare) – Avulsion of the inferior pole – Medial avulsion (usually associated with dislocation of the patella) – Superolateral avulsion (rare and mistaken for bipartite patella).
Stress fractures	They are caused by repetitive forces. There are two well-defined groups, athletes and children with infantile cerebral palsy (ICP). In athletes the fracture line may be longitudinal or transverse. In children with ICP they occur in the inferior pole and give an image of fragmentation of the patella.
Osteochondral fractures of the articular surface	They are caused by direct trauma to the joint.

Fractures of the ossification nucleus are the most frequent and are the result of high energy traumas, usually the patients present intense pain with hemarthrosis and in most cases the fractures are open. In this type of injury, fractures of the femur and tibia may occur in association, either isolated or combined. Treatment in non-displaced fractures consists of the application of cast immobilization for four to six weeks, and in displaced fractures, osteosynthesis by means of screws or locks is justified. The approach for reduction can be by arthrotomy or arthroscopically assisted reduction.[23,24]
Avulsion fractures are very typical of pediatric ages and affect any peripheral segment of the patella, with a large portion of cartilaginous tissue with or without bone layer. Avulsion of the lower pole (Figure 1A) is one of the most frequent and is characterized by the impossibility to extend the leg and by the

presence of the hatchet sign associated with hemarthrosis. Plain radiography cannot detect it if there is no bone fragment. Treatment is surgical, by reanchoring the disinsertion. In children under 10 years of age the use of non-absorbable sutures is preferred (Figure 1B) and in those older than this age the use of wires and Kirchners is justified. When the diagnosis is late it is difficult to differentiate it from Sinding-Larsen-Johansson disease, but it should be remembered that this does not present a high patella, as it can happen in patients with avulsive fractures of the inferior pole.[25,26,27]

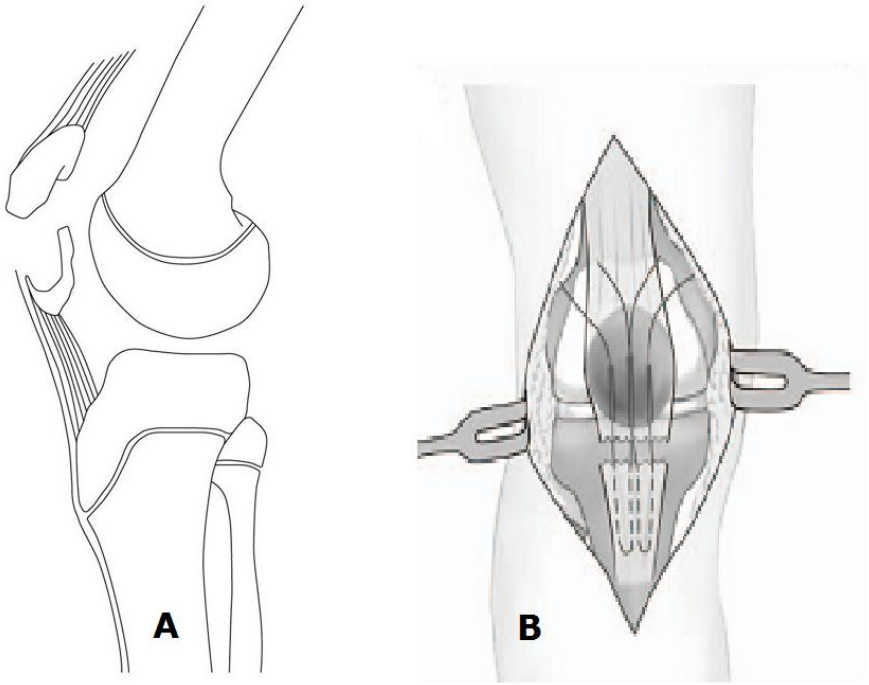

Figure 1. A) Avulsive fracture of the inferior pole of the patella. **B)** Reanchoring by sutures

In patients with avulsive fractures of the patella, the possibility of a bifocal lesion characterized by avulsion of the inferior pole of the patella and of the insertion of the patellar tendon in the anterior tuberosity of the tibia must be taken into account (Figure 2A).[28] This type of traumatic condition is infrequent, so its diagnosis requires a high index of suspicion. Treatment in these cases is surgical, by reinsertion of the avulsed structures (Figure 2B).

Stress fractures occur in two groups of patients, the first in athletes and the second in patients with ICP. The former manifest clinically by pain of varying intensity, which increases with physical activity. Occasionally, the presence of bone callus confirms the diagnosis. Treatment is usually conservative, with immobilization and, in case of persistent pain, surgical intervention for removal of the fractured fragment is warranted. In patients with ICP, lower pole fractures that respond favorably to cast immobilization with the knee in extension are frequently encountered.[29,30,31]

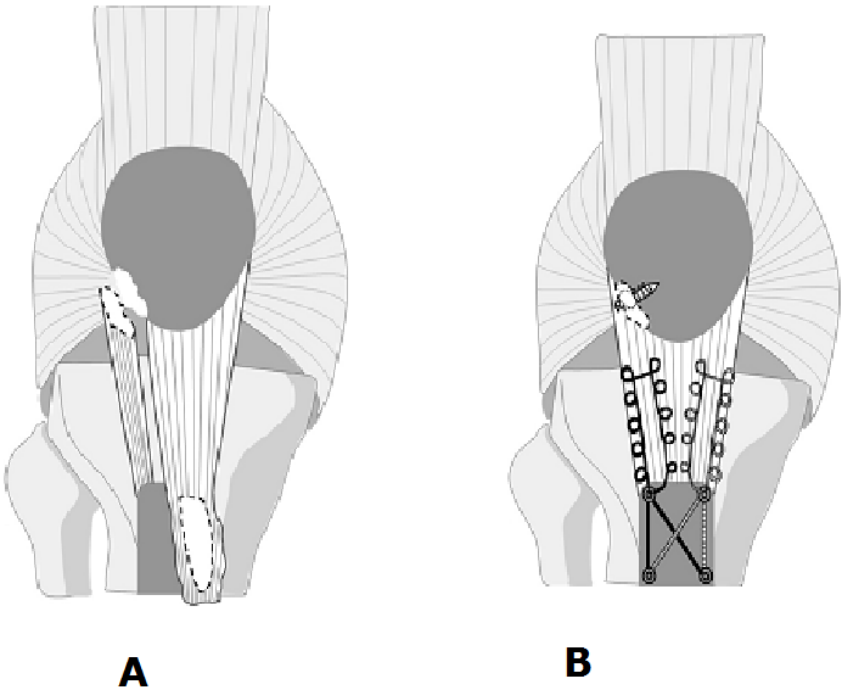

Figure 2. A) Bifocal injury consisting of avulsed fracture of the inferior pole of the patella and the insertion of the patellar tendon. **B)** Repair of both traumatic conditions[28]

Osteochondral fractures of the patella are difficult to diagnose and only advanced imaging tests such as computerized axial tomography and magnetic resonance imaging provide elements that confirm this lesion, in addition to the arthroscopic approach.[32,33]

In general, conservative treatment is justified in patients with non-displaced fractures or displacement of less than three millimeters and consists of placing an inguino-malleolar cast for a period of four to six weeks. Surgical modalities are applicable in patients with displacement and joint incongruence greater than two or three millimeters, the main techniques include wire cerclage, tension bands, suturing and screws.[34,35,36]

The most reported complications in patients with this traumatic condition are:[1,20,37]

- Associated fractures of the femur and tibia: the results in these cases are worse than in patients with isolated injuries. In case of displaced fracture, surgical treatment is warranted.
- Quadriceps weakness: usually occurs after an undiagnosed fracture or inadequate treatment resulting in elongation of this anatomical structure.
- High patella: occurs as a result of elongation of the extensor mechanism and is associated with quadriceps weakness and atrophy.
- Post-traumatic osteoarthritis: these are triggered by articular surface involvement, especially osteochondral fractures.

Among the most infrequent complications are: chronic infection if surgery is necessary, avascular necrosis of the patella and pseudoarthrosis.

CONCLUSIONS

Kneecap fractures in children have very specific characteristics, which require knowledge of the anatomy of the immature skeleton, the mechanisms of production, classifications and types of treatment available for these patients.

BIBLIOGRAPHIC REFERENCES

1. Egol KA, Koval KJ, Zuckerman J. Handbook of Fractures. 6th ed. Philadelphia: Wolters Kluwer; 2020. p. 666-668.
2. Bailey MEA, Wei R, Bolton S, Richards RH. Paediatric injuries around the knee: Bony injuries. Injury [Internet]. 2020 [cited 05/30/2022];51(3):611-619. Available at: https://pubmed.ncbi.nlm.nih.gov/32067766/. https://doi.org/10.1016/j.injury.2019.12.033
3. Golshteyn G, Katsman A. Pediatric Trauma. Clin Podiatr Med Surg [Internet]. 2022 [cited 05/30/2022];39(1):57-71. Available at: https://pubmed.ncbi.nlm.nih.gov/34809795/. https://doi.org/10.1016/j.cpm.2021.08.001
4. Christino MA, Kocher MS. The Paediatric Knee. En: LaPrade RF, Chahla J. Evidence Based Management of Complex Knee Injuries. Philadelphia: Elsevier; 2021. p. 396-415.
5. Kowalczyk AD, Geminiani ET, Dahlberg BW, Micheli LJ, Sugimoto D. Pediatric and Adolescent Figure Skating Injuries: A 15-Year Retrospective Review. Clin J Sport Med [Internet]. 2021 [cited 05/30/2022];31(3):295-303. Available at: https://pubmed.ncbi.nlm.nih.gov/30985309/. https://doi.org/10.1097/jsm.0000000000000743
6. Young EY, Shlykov MA, Hosseinzadeh P, Abzug JM, Baldwin KD, Milbrandt TA. Fractures around the knee in Children. Instr Course Lect [Internet]. 2019 [cited 05/30/2022];68:463-472. Available at: https://pubmed.ncbi.nlm.nih.gov/32032063/
7. Cruz AI Jr, Richmond CG, Tompkins MA, Heyer A, Shea KG, Beck JJ. What's New in Pediatric Sports Conditions of the Knee? J Pediatr Orthop [Internet]. 2018 [cited 05/30/2022];38(2):e66-e72. Available at: https://pubmed.ncbi.nlm.nih.gov/29189538/. https://doi.org/10.1097/bpo.0000000000001107
8. Levene R, Fein DM, Grossman JP. Knee Trauma. Pediatr Rev [Internet]. 2022 [cited 05/30/2022];43(1):54-57. Available at: https://pubmed.ncbi.nlm.nih.gov/35229128/. https://doi.org/10.1542/pir.2021-004991
9. Devana SK, Trivellas A, Bennett A, Jackson N, Beck JJ. Clinical and radiographic differentiation of pediatric patellar sleeve fractures and other inferior pole pathologies. Am J Sports Med [Internet]. 2022 [cited 05/30/2022];50(4):977-983. Available at: https://pubmed.ncbi.nlm.nih.gov/35142232/. https://doi.org/10.1177/03635465221073995
10. Ramo B, Ellis HB. Lower extremity injuries. En: Herring JA. Tachdjian's Pediatric Orthopaedics. 6th ed. Philadelphia: Elsevier: 2022. p. 1344-1348.
11. Woernle M, Fechisin JP. The Pediatric Knee and proximal tibia. Pediatr Clin North Am [Internet]. 2020 [cited 05/30/2022];67(1):153-167. Available at:

https://pubmed.ncbi.nlm.nih.gov/31779830/. https://doi.org/10.1016/j.pcl.2019.09.012
12. MacDonald J, Rodenberg R, Sweeney E. Acute Knee Injuries in Children and Adolescents: A Review. JAMA Pediatr [Internet]. 2021 [cited 05/30/2022];175(6):624-630. Available at: https://pubmed.ncbi.nlm.nih.gov/33749718/. https://doi.org/10.1001/jamapediatrics.2020.6130
13. Maloney E, Stanescu AL, Ngo AV, Parisi MT, Iyer RS. The pediatric patella: normal development, anatomical variants and malformations, stability, imaging, and injury patterns. Semin Musculoskelet Radiol [Internet]. 2018 [cited 05/30/2022];22(1):81-94. Available at: https://pubmed.ncbi.nlm.nih.gov/29409075/. https://doi.org/10.1055/s-0037-1608004
14. Tuca M, Pineda T. Lesiones traumáticas de rodilla en niños y adolescentes. Rev Méd Clín Las Condes [Internet]. 2021 [cited 05/30/2022];32(3):319-328. Available at: https://www.elsevier.es/es-revista-revista-medica-clinica-las-condes-202-articulo-lesiones-traumaticas-de-rodilla-en-S0716864021000493. https://doi.org/10.1016/j.rmclc.2021.01.009
15. Neubauer T. Pediatric injuries of the knee joint. Unfallchirurg [Internet]. 2019 [cited 05/30/2022];122(1):5. Available at: https://pubmed.ncbi.nlm.nih.gov/30656369/. https://doi.org/10.1007/s00113-018-0587-3
16. Samet JD. Pediatric Sports Injuries. Clin Sports Med [Internet]. 2021 [cited 05/30/2022];40(4):781-799. Available at: https://www.scholars.northwestern.edu/en/publications/pediatric-sports-injuries. https://doi.org/10.1016/j.csm.2021.05.012
17. Bauer KL. Osteochondral injuries of the knee in pediatric patients. J Knee Surg [Internet]. 2018 [cited 05/30/2022];31(5):382-391. Available at: https://pubmed.ncbi.nlm.nih.gov/29381884/. https://doi.org/10.1055/s-0038-1625956
18. Denduluri SK, Gamble JG. Bilateral medial patella sleeve fractures in a child: a case report. JBJS Case Connect [Internet]. 2020 [cited 05/30/2022];10(2):e1900533. Available at: https://pubmed.ncbi.nlm.nih.gov/32649152/. https://doi.org/10.2106/jbjs.cc.19.00533
19. Scully WF, Rumley MJC, Caskey PM. Bilateral patellar stress fractures in a skeletally immature athlete: a case report. JBJS Case Connect [Internet]. 2019 [cited 05/30/2022];9(4):e0047. Available at: https://pubmed.ncbi.nlm.nih.gov/31850960/. https://doi.org/10.2106/jbjs.cc.19.00047
20. Sawyer JR, Spence DD. Fractures and Dislocations in Children. En: Azar FM, Beaty JH. Campbell's Operative Orthopaedics. 14th ed. Philadelphia: Elsevier; 2021. p. 1599-1601.
21. Sessions WC, Herring M, Truong WH. Extensor mechanism injury in the pediatric population-a clinical review. J Knee Surg [Internet]. 2018 [cited 05/30/2022];31(6):490-497. Available at: https://pubmed.ncbi.nlm.nih.gov/29409066/. https://doi.org/10.1055/s-0038-1625955
22. Cahuzac J. Fracturas y luxaciones de la rótula. En: Pablos J, Gónzalez Herranz P. Apuntes de Fracturas Infantiles. Madrid: Ed Ergon; 1999. p. 311-16.
23. Bukva B, D'Hooghe P, Poberaj B, Alkhelaifi K, Hutchinson M, Landreau P. A combined tension-band braided polyester and suture button technique is a valuable

treatment alternative for transverse patellar fractures in athletes. Musculoskelet Surg [Internet]. 2019 [cited 05/30/2022];103(3):283-287. Available at: https://pubmed.ncbi.nlm.nih.gov/30617732/. https://doi.org/10.1007/s12306-019-00587-1

24. Calderaro C, Falciglia F, Giordano M, Aulisa AG, Toniolo RM. Bifocal avulsion of the patellar tendon from the distal patella and tibial tuberosity in a skeletally immature patient: a case report. JBJS Case Connect [Internet]. 2020 [cited 05/30/2022];10(4):e20.00065. Available at: https://pubmed.ncbi.nlm.nih.gov/33512923/. https://doi.org/10.2106/jbjs.cc.20.00065
25. Georgiadis AG, Comadoll SM. Patellar sleeve fracture: open reduction and internal fixation. JPOSNA [Internet]. 2021 [cited 05/30/2022];3(4):1-6. Available at: https://www.jposna.org/ojs/index.php/jposna/article/view/367. https://doi.org/10.55275/JPOSNA-2021-367
26. Güler Y, Arslanoğlu F, Korkmaz O, Hakyemez ÖS, Ateş G, Çaçan MA. Missed sleeve fracture of the superior pole of patella. Acta Chir Orthop Traumatol Cech [Internet]. 2020 [cited 05/30/2022];87(2):127-128. Available at: https://pubmed.ncbi.nlm.nih.gov/32396514/
27. Perkins CA, Egger AC, Willimon SC. Transosseous repair of patellar sleeve fractures: a case series and surgical technique guide. J Knee Surg [Internet]. 2022 [cited 05/30/2022];35(12):1326-1332. Available at: https://pubmed.ncbi.nlm.nih.gov/33545727/. https://doi.org/10.1055/s-0041-1723013
28. Sidharthan S, Schlichte LM, Green DW, Scher DM, Fabricant PD. Bifocal patellar tendon avulsion fractures in children and adolescents: diagnosis and treatment considerations for a unique injury pattern. Arthrosc Sports Med Rehabil [Internet]. 2021 [cited 05/30/2022];3(1):e97-e103. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7879166/. https://doi.org/10.1016/j.asmr.2020.08.013
29. Lo CH, Chen CH. Comparison of minimally invasive percutaneous fixation and open reduction internal fixation for patella fractures: a meta-analysis. J Orthop Surg Res [Internet]. 2021 [cited 05/30/2022];16(1):506. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8369684/. https://doi.org/10.1186/s13018-021-02612-1
30. Schmidt-Hebbel A, Eggers F, Schütte V, Achtnich A, Imhoff AB. Patellar sleeve avulsion fracture in a patient with Sinding-Larsen-Johansson syndrome: a case report. BMC Musculoskelet Disord [Internet]. 2020 [cited 05/30/2022];21(1):267. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7181494/. https://doi.org/10.1186/s12891-020-03297-z
31. Sousa PL, Stuart MJ, Prince MR, Dahm DL. Nonoperative management of minimally displaced patellar sleeve fractures. J Knee Surg [Internet]. 2021 [cited 05/30/2022];34(3):242-246. Available at: https://pubmed.ncbi.nlm.nih.gov/31434147/. https://doi.org/10.1055/s-0039-1694742
32. Khan SA, Baghdadi S, Carey JL, Moores TS, Sheth NP, Ganley T. Osteochondral fractures after patellar dislocation: current concepts. J Am Acad Orthop Surg Glob Res Rev [Internet]. 2021 [cited 05/30/2022];5(12). Available at: https://pubmed.ncbi.nlm.nih.gov/34860734/. https://doi.org/10.5435/JAAOSGlobal-D-21-00155

33. Siddiqui R, Singh A, Cullinan C. Superior pole sleeve fracture of the patella in an adolescent: a case report. JBJS Case Connect [Internet]. 2020 [cited 05/30/2022];10(3):e2000007. Available at: https://pubmed.ncbi.nlm.nih.gov/32865951/. https://doi.org/10.2106/jbjs.cc.20.00007
34. Sudah S, Nasra M, Michel C, Dijanic C, Kerrigan D, Curatolo E. Patella sleeve fracture with medial patellofemoral ligament tear and lateral femoral condyle fracture in an adolescent: a case report. JBJS Case Connect [Internet]. 2021 [cited 05/30/2022];11(4). Available at: https://pubmed.ncbi.nlm.nih.gov/34669654/. https://doi.org/10.2106/jbjs.cc.21.00232
35. Morley HL, Sharma A, Whittingham-Jones P. Patella incarceration with associated patella fracture: a rare case of a paediatric patient with no associated femoral fracture. BMJ Case Rep [Internet]. 2018 [cited 05/30/2022];2018:bcr2018226603. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6144349/. https://doi.org/10.1136/bcr-2018-226603
36. Schütte V, Schmidt-Hebbel A, Imhoff AB, Achtnich A. Patellar sleeve fractures: Bracing and augmentation technique with suture tape. Oper Orthop Traumatol [Internet]. 2019 [cited 05/30/2022];31(1):56-62. Available at: https://pubmed.ncbi.nlm.nih.gov/30539194/. https://doi.org/10.1007/s00064-018-0581-5
37. Shao JY, Yang YP, Ao YF. Chronic bilateral sleeve fracture of the patellae in a healthy child: a case report. Chin Med J (Engl) [Internet]. 2020 [cited 05/30/2022];133(14):1744-1746. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7401739/. https://doi.org/10.1097/cm9.0000000000000926

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.