Pediatric Clavicle Fractures

Subjects: Orthopedics
Contributor: Lisa van der Water

Clavicle fractures are commonly seen in the pediatric and adolescent populations. In contrast, congenital pseudarthrosis of the clavicle is rare. Although both conditions may present with similar signs and symptoms, especially in the very young, clear differences exist. Clavicle fractures are often caused by trauma and are tender on palpation, while pseudarthrosis often presents with a painless protuberance on the clavicle, which becomes more prominent as the child grows. Its presence may only become apparent after trauma, as it is usually asymptomatic.

fracture clavicle children pseudarthrosis pediatric

1. Epidemiology

Clavicle fractures account for 10–15% of all pediatric fractures [1]. The majority of patients with a clavicle fracture are male (91.2%), and most clavicle fractures are seen between the ages of 10 and 19 years (incidence rate of 91.7 per 100,000) [1][2]. Fractures on the left side (58%) and on the non-dominant side (56%) are slightly more common [3]. Most clavicle fractures occur in the middle section of the bone, accounting for 70% to 95% of all pediatric clavicle fractures [1][4][5]. Displaced fractures of the clavicle are relatively common, ranging from 28% to 67% of all clavicle fractures in children and adolescents [1][3][5][6].

Clavicle fractures occur most frequently as a result of sports (66%), horseplay (12%), riding a bike (6%), a fall (6%) or another type of accident (3%) [3]. However, clavicle fractures may also occur during childbirth, particularly in the case of shoulder dystocia [7][8]. Although less than 4% of all children are born with this fracture, it is the most common fracture during childbirth, accounting for almost a third of all birth traumas [7][8][9].

On the other hand, congenital pseudarthrosis of the clavicle is a rare condition, and currently, available evidence relies on case reports (approximately 200 in total), with no studies reporting the incidence [10]. Congenital pseudarthrosis occurs more frequently in females and most commonly on the right side [10][5]. Isolated left clavicle pseudarthrosis occurs in less than 10%, and in most cases, presents in combination with dextrocardia or situs inversus [10]. Bilateral pseudarthrosis has been reported in about 10% of cases, often in combination with a high subclavian artery and cervical ribs or vertical upper ribs [10].

Congenital pseudarthrosis is often associated with abnormalities of ossification during the embryonic stage and is associated with genetic syndromes like Ehlers-Danlos, Al-Awadi/Ras-Rothschild, Kabuki and Prader-Willi [10].

1.1. Anatomy

Development of Clavicle

The clavicle develops from two ossification centers that are initially connected by pre-cartilage surrounded by perichondrium [10]. Physiological ossification of the clavicle occurs during the fourth week of gestation, and the two ossification centers fuse near the seventh week [10]. The epiphysis of the medial part of the clavicle does not ossify until the age of 20, and the lateral epiphysis does not ossify until the age of 25 years [1].

1.2. Trauma Mechanism

Most fractures are caused by blunt trauma to the shoulder or upper arm (60%), trauma to the clavicle or chest (24%) or a fall on an outstretched arm (11%) [3].

Concomitant fractures are rare in children and occur mostly in high-energy accidents involving sports or motorized vehicles [1][11]. The most common concomitant fractures are those of the ribs, spine, extremities and facial bones [1]. However, other concomitant injuries such as brachial plexopathy, compression of the subclavian vein and other neurovascular injuries are more common [1][6].

Another important trauma mechanism of clavicle fracture is peri-natal injury. Birth fractures are associated with shoulder dystocia and difficult delivery [7]. Risk factors for clavicle fractures are similar to risk factors related to a difficult delivery and shoulder dystocia, namely: instrumented delivery, macrosomia, post-term delivery, procedural induction of labor, prolonged labor, advanced maternal age, multiparity and excessive weight gain during the pregnancy [7]. Peri-natal clavicle fractures are often seen in combination with a fractured humerus, brachial plexus injury and injuries to the phrenic and recurrent laryngeal nerves [7]. In rare cases, an iatrogenic clavicle fracture is unavoidable to ensure successful delivery.

1.3. Development of Pseudarthrosis

Pseudarthrosis of the clavicle is characterized by the incomplete or absent union of the two ossification centers [10]. Although the exact cause of pseudarthrosis is unknown, several theories have been developed as to why the fusion of the two ossification centers fails [10]. One theory is that the excessive pressure from the pulsing subclavian artery during the development of the clavicle causes non-union of the ossification centers, especially if cervical ribs are present, which add to the increased pressure [10]. Another theory is that the non-union is caused by an altered intrauterine position of the fetus and cranial localization of the right subclavian artery [10]. Additionally, rare case reports [12][13][14][15][16] of family members with pseudarthrosis suggest inheritance to attribute to the development of pseudarthrosis, although there is a lack of conclusive evidence to support this hypothesis.

1.4. Classification of Pseudarthrosis

Kite proposed a classification system for congenital pseudarthrosis of the clavicle based on the differences in anatomy, clinical representation and pathology [10][17].

Type I includes patients who have clavicular non-union at birth, caused by hypoplasia of the distal fragment [10][17]. Pressure on the protuberance is painful, and radiographs show a larger medial fragment than lateral fragment with clear spacing between them [10][17]. For this type, the distance between the fragments and their positioning should be assessed before surgery is considered [10][17].

Type II includes patients with congenital bone deficiency who have a physiologically formed clavicle at birth which is more fragile and prone to fractures [10][17]. For this type, surgery could be considered after a fracture has occurred [10][17].

2. Treatment

2.1. Fractures

2.1.1. Non-Operative Treatment

Non-operative treatment is indicated for all fractures without displacement or other complicating factors [1][18]. The majority of clavicle fractures are treated conservatively (**Figure 1**b), even with significant shortening and total displacement, because children have the ability to reconstitute fracture shortening and displacement that would need surgery in adults [5][18][19][20][21][22][23][24]. To immobilize the fracture, a supportive sling, collar 'n' cuff or figure-of-eight bandage is prescribed for several weeks [5][18][19]. The exact length of immobilization is dependent on the severity of the fracture, the age of the child and the amount of pain [5][18][19]. The children are also instructed to avoid high-risk activities [5].

Figure 1. (**a**) Right clavicle fracture (Group I) with extreme displacement. (**b**) After 5 weeks of conservative treatment, early callus formation is visible.

Outcomes of non-operative treatment are generally satisfactory in children and adolescents [25][26][27]. Most patients prefer the cosmetic outcome of conservative treatment [25]. However, in adolescents, conservative treatment may lead to longer functional recovery and longer time until a stable union is achieved, compared to younger children [28][29]. Non-union and mal-union are rare in children but occur slightly more frequently in the non-operative group [5][28][29].

2.1.2. Operative Treatment

A small percentage of fractures require primary surgical fixation (1.6%) [5]. Fixation is indicated in the case of an open fracture, imminent open fracture, neurovascular injury, symptomatic non-union, symptomatic malunion, floating shoulder or polytrauma [1][5][22][23][30]. Relative indications for operative treatment are significantly displaced fractures (>100% of shaft width) (**Figure 1**a, **Figure 2**a and **Figure 3**a), severe comminution and significantly shortened fractures (> 15–20 mm absolute or > 14% relative shortening) [1][5][22][23][30][31][32][33][34][35][36][37].

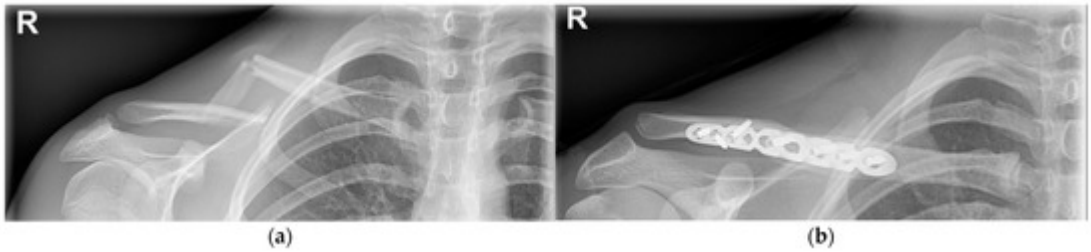

Figure 2. (**a**) Segmental right clavicle fracture (Group I), with extreme displacement. (**b**) Surgical fixation using the plate-and-screw method.

Figure 3. (**a**) Right clavicle fracture (Group I) with extreme displacement. (**b**) Surgical fixation with an intramedullary wire.

The indication for surgery for fractures with significant shortening is actively discussed in the literature. Some studies have shown beneficial effects of surgery in children with a significantly shortened clavicle fracture, such as a lower incidence of mal-union and non-union [38][22][30][31][33][34][35][36][37][39][40]. However, other studies found no significant difference in outcome compared to the conservative treatment for shortened fractures [23][24][36][41]. This ambiguity is partially caused by the different methods of measuring clavicle shortening: end-to-end, cortex-to-corresponding cortex and relative shortening compared to the uninjured side [3]. Different methods may result in different cut-off values for the amount of shortening [3]. Therefore, an exact cut-off value for the amount of shortening that would be an indication for surgery cannot be concluded from the literature. In children and adolescents, clavicle shortening should be expressed in percentage shortening relative to the uninjured clavicle [3][22]. Until further consensus is reached, the choice of treatment for fracture shortening should be based on additional complicating factors, age, years of growth remaining, potential for remodeling and level of functional demand [22][30][40].

Several internal fixation methods can be used, such as plate and screw fixation (**Figure 2**b), screw-only fixation and intramedullary fixation (**Figure 3**b) [5]. Plate and screw fixation is the most commonly used technique [5]. Plate fixation has advantages over the other techniques: it provides strong fixation and compression of the small fractured fragments [32]. However, it requires an open exposure with corresponding soft tissue damage and risk of infection [32]. To reduce the size of the incision, other techniques such as the minimally invasive plate osteosynthesis (MIPO) technique, screw fixation only or intramedullary nail fixation can be used [32].

Outcomes after surgical treatment are generally satisfactory, yet not (significantly) superior to non-operative treatment [25][26][27]. There is an incongruence in the literature regarding the superiority of surgical treatment or non-operative treatment in children and adolescents. Some studies report superior outcomes in adolescents after surgery compared to non-operative treatment [28][29]. However, other studies report no clear difference in outcomes between operative and non-operative treatment in children or adolescents [5][26][27][32]. Possible advantages of surgery for adolescents are shorter recovery time, fewer cases of mal-union and non-union and shorter time to achieve union [28][29][30][31][32][35][37][40]. However, conservative treatment comes with a lower risk of complications and remains the preferred treatment in the far majority of pediatric patients.

2.2. Pseudarthrosis

2.2.1. Non-Operative Treatment

The majority of patients are treated conservatively (i.e., observation only, no interventions), especially if they experience minimal symptoms and do not have esthetic complaints due to the protuberance [6][10]. Outcomes after non-operative treatment are generally excellent; most patients do not experience any pain, discomfort or limited range of motion .

2.2.2. Operative Treatment

Indications for surgical treatment are progressive pain, functional limitation and late-onset thoracic outlet syndrome [10]. However, most operations are performed for cosmetic reasons [10]. Surgery is considered in Kite type I patients, where the fragments are less than 1 cm apart [10][17]. A displacement greater than 1 cm has a much higher incidence of nonconsolidation and complications after surgery [10][17]. Several surgical treatment options are used: resection of the focus of the pseudarthrosis with the option of using a bone graft, osteosynthesis or both [10]. For stabilization, different techniques are used: an intramedullary Kirschner-wire, plate and screws, screws only, a Steinmann intramedullary pin or external fixation [10][17]. Post-operative treatment includes immobilization with a Velpeau sling or Desault bandage for four to six weeks [2]. Outcomes after surgical treatment are generally successful and complications are rare [10]. Non-union is the most common complication and is often an indication for revision surgery .

2.3. Revision Surgery

Revision surgery is required in the case of a refracture and non-union due to failed osteosynthesis [1][4][32]. Non-union is rare and occurs almost exclusively in patients with complete fracture displacements and refractures [4][5]. The incidence of non-union increases with increased age [5]. This may be related to skeletal maturity and more forceful trauma, which increases the chance of completely displaced fractures and concomitant injuries [5].

Bone-grafting is often used in the case of non-union, but is increasingly difficult with increased displacement . Kubiak and Slongo reported that in a study of 15 patients that underwent wire or nail fixation, all patients had to undergo revision surgery . Furthermore, Luo et al. reported that out of 23 patients who were surgically treated (19 with a plate and 4 with an intramedullary nail), 5 (21.7%) experienced complications (refracture, prominence of the implant and non-union due to implant failure), of whom 4 needed a revision surgery [4]. Additionally, many patients prefer to have the hardware removed due to discomfort or esthetic complaints [4].

References

1. van der Meijden, O.A.; Gaskill, T.R.; Millett, P.J. Treatment of clavicle fractures: Current concepts review. J. Shoulder Elb. Surg. 2012, 21, 423–429.
2. van Tassel, D.; Owens, B.D.; Pointer, L.; Moriatis Wolf, J. Incidence of clavicle fractures in sports: Analysis of the NEISS Database. Int J. Sports Med. 2014, 35, 83–86.
3. Ellis, H.B.; Li, Y.; Bae, D.S.; Kalish, L.A.; Wilson, P.L.; Pennock, A.T.; Nepple, J.J.; Willimon, S.C.; Spence, D.D.; Pandya, N.K.; et al. Descriptive Epidemiology of Adolescent Clavicle Fractures: Results From the FACTS (Function after Adolescent Clavicle Trauma and Surgery) Prospective, Multicenter Cohort Study. Orthop J. Sports Med. 2020, 8.
4. Luo, T.D.; Ashraf, A.; Larson, A.N.; Stans, A.A.; Shaughnessy, W.J.; McIntosh, A.L. Complications in the treatment of adolescent clavicle fractures. Orthopedics 2015, 38, e287–e291.
5. Hughes, K.; Kimpton, J.; Wei, R.; Williamson, M.; Yeo, A.; Arnander, M.; Gelfer, Y. Clavicle fracture nonunion in the paediatric population: A systematic review of the literature. J. Child. Orthop. 2018, 12, 2–8.
6. O'Neill, B.J.; Molloy, A.P.; Curtin, W. Conservative Management of Paediatric Clavicle Fractures. Int. J. Pediatr. 2011, 2011, 172571.
7. Yenigül, A.E.; Yenigül, N.N.; Başer, E.; Özelçi, R. A retrospective analysis of risk factors for clavicle fractures in newborns with shoulder dystocia and brachial plexus injury: A single-center experience. Acta Orthop. Traumatol. Turc. 2020, 54, 609–613.
8. Beall, M.H.; Ross, M.G. Clavicle fracture in labor: Risk factors and associated morbidities. J. Perinatol. 2001, 21, 513–515.
9. Linder, N.; Linder, I.; Fridman, E.; Kouadio, F.; Lubin, D.; Merlob, P.; Yogev, Y.; Melamed, N. Birth trauma-risk factors and short-term neonatal outcome. J. Matern. Neonatal Med. 2013, 26, 1491–

1495.

10. de Figueiredo, M.J.P.S.S.; Dos Reis Braga, S.; Akkari, M.; Prado, J.C.L.; Santili, C. Congenital pseudarthrosis of the clavicle. Rev. Bras. Ortop. 2012, 47, 21–26.
11. O'Neill, B.J.; Hirpara, K.M.; O'Briain, D.; McGarr, C.; Kaar, T.K. Clavicle fractures: A comparison of five classification systems and their relationship to treatment outcomes. Int. Orthop. 2011, 35, 909–914.
12. Alldred, A.J. Congenital pseudarthrosis of the clavicle. J. Bone Jt. Surg. Br. 1963, 45, 312–319.
13. Price, B.D.; Price, C.T. Familial congenital pseudoarthrosis of the clavicle: Case report and literature review. Iowa Orthop. J. 1996, 16, 153–156.
14. Toledo, L.C.; MacEwen, G.D. Severe complication of surgical treatment of con-genital pseudarthrosis of the clavicle. Clin. Orthop. Relat. Res. 1979, 139, 64–67.
15. Shim, J.S.; Chang, M.J. Congenital pseudarthrosis of the clavicle—Report of 4 cases treated with surgical methods. J. Korean Orthop. Assoc. 2008, 43, 396–399.
16. Persiani, P.; Molayem, I.; Villani, C.; Cadilhac, C.; Glorion, C. Surgical treatment of congenital pseudarthrosis of the clavicle: A report on 17 cases. Acta Orthop. Belg. 2008, 74, 161–166.
17. Kite, J.H. Congenital pseudarthrosis of the clavicle. South. Med. J. 1968, 61, 703–710.
18. Kihlström, C.; Möller, M.; Lönn, K.; Wolf, O. Clavicle fractures: Epidemiology, classification and treatment of 2 422 fractures in the Swedish Fracture Register; an observational study. BMC Musculoskelet. Disord. 2017, 18, 82.
19. Andersen, K.; Jensen, P.O.; Lauritzen, J. Treatment of clavicular fractures. Figure-of-eight bandage versus a simple sling. Acta Orthop. Scand. 1987, 58, 71–74.
20. Randsborg, P.H.; Fuglesang, H.F.; Røtterud, J.H.; Hammer, O.L.; Sivertsen, E.A. Long-term patient-reported outcome after fractures of the clavicle in patients aged 10 to 18 years. J. Pediatr. Orthop. 2014, 34, 393–399.
21. Schulz, J.; Moor, M.; Roocroft, J.; Bastrom, T.P.; Pennock, A.T. Functional and radiographic outcomes of nonoperative treatment of displaced adolescent clavicle fractures. J. Bone Jt. Surg. Am. 2013, 95, 1159–1165.
22. Leal-Oliva, A.; Mora-Ríos, F.G.; Mejía-Rohenes, C.; López-Marmnolejo, A.; Acevedo-Cabrera, M.J. Acortamiento relativo de clavícula en fracturas pediátricas: Su importancia en la decisión del tratamiento conservador . Acta Ortop. Mex. 2014, 28, 82–87.
23. Swarup, I.; Maheshwer, B.; Orr, S.; Kehoe, C.; Zhang, Y.; Dodwell, E. Intermediate-Term Outcomes Following Operative and Nonoperative Management of Midshaft Clavicle Fractures in

Children and Adolescents: Internal Fixation May Improve Outcomes. JB JS Open Access 2021, 6, e20.00036.

24. McGraw, M.A.; Mehlman, C.T.; Lindsell, C.J.; Kirby, C.L. Postnatal growth of the clavicle: Birth to 18 years of age. J. Pediatr. Orthop. 2009, 29, 937–943.
25. Riiser, M.O.; Molund, M. Long-term Functional Outcomes and Complications in Operative Versus Nonoperative Treatment for Displaced Midshaft Clavicle Fractures in Adolescents: A Retrospective Comparative Study. J. Pediatr. Orthop. 2021, 41, 279–283.
26. Scott, M.L.; Baldwin, K.D.; Mistovich, R.J. Operative Versus Nonoperative Treatment of Pediatric and Adolescent Clavicular Fractures. JBJS Rev. 2019, 7, e5.
27. Mukhtar, I.A.; Yaghmour, K.M.; Ahmed, A.F.; Ibrahim, T. Flexible intramedullary nailing versus nonoperative treatment for paediatric displaced midshaft clavicle fractures. J. Child. Orthop. 2018, 12, 104–110.
28. McIntosh, A.L. Surgical treatment of adolescent Clavicle Fractures: Results and complications. J. Pediatr. Orthop. 2016, 36 (Suppl. 1), S41–S43.
29. Song, M.H.; Yun, Y.H.; Kang, K.; Hyun, M.J.; Choi, S. Nonoperative versus operative treatment for displaced midshaft clavicle fractures in adolescents: A comparative study. J. Pediatr. Orthop. Part B 2019, 28, 45–50.
30. Fanter, N.J.; Kenny, R.M.; Baker, C.L., III; Baker, C.L., Jr. Surgical treatment of clavicle fractures in the adolescent athlete. Sports Health 2015, 7, 137–141.
31. Pecci, M.; Kreher, J.B. Clavicle fractures. Am. Fam. Physician 2008, 77, 65–70.
32. Kim, H.Y.; Yang, D.S.; Bae, J.H.; Cha, Y.H.; Lee, K.W.; Choy, W.S. Clinical and Radiological Outcomes after Various Treatments of Midshaft Clavicle Fractures in Adolescents. Clin. Orthop. Surg. 2020, 12, 396–403.
33. Lazarides, S.; Zafiropoulos, G. Conservative treatment of fractures at the middle third of the clavicle: The relevance of shortening and clinical outcome. J. Shoulder Elb. Surg. 2006, 15, 191–194.
34. Hill, J.M.; McGuire, M.H.; Crosby, L.A. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J. Bone Jt. Surg. Br. 1997, 79, 537–539.
35. Herzog, M.M.; Whitesell, R.C.; Mac, L.M.; Jackson, M.L.; Culotta, B.A.; Axelrod, J.R.; Busch, M.T.; Willimon, S.C. Functional outcomes following non-operative versus operative treatment of clavicle fractures in adolescents. J. Child. Orthop. 2017, 11, 310–317.
36. Bae, D.S.; Shah, A.S.; Kalish, L.A.; Kwon, J.Y.; Waters, P.M. Shoulder motion, strength, and functional outcomes in children with established malunion of the clavicle. J. Pediatr. Orthop. 2013, 33, 544–550.

37. Vander Have, K.L.; Perdue, A.M.; Caird, M.S.; Farley, F.A. Operative versus nonoperative treatment of midshaft clavicle fractures in adolescents. J. Pediatr. Orthop. 2010, 30, 307–312.
38. Matsumura, N.; Ikegami, H.; Nakamichi, N.; Nakamura, T.; Nagura, T.; Imanishi, N.; Aiso, S.; Toyama, Y. Effect of shortening deformity of the clavicle on scapular kinematics: A cadaveric study. Am. J. Sports Med. 2010, 38, 1000–1006.
39. Ledger, M.; Leeks, N.; Ackland, T.; Wang, A. Short malunions of the clavicle: An anatomic and functional study. J. Shoulder Elb. Surg. 2005, 14, 349–354.
40. Pandya, N.K.; Namdari, S.; Hosalkar, H.S. Displaced clavicle fractures in adolescents: Facts, controversies, and current trends. J. Am. Acad. Orthop. Surg. 2012, 20, 498–505.
41. Parry, J.A.; Van Straaten, M.; Luo, T.D.; Simon, A.L.; Ashraf, A.; Kaufman, K.; Larson, A.N.; Shaughnessy, W.J. Is There a Deficit After Nonoperative Versus Operative Treatment of Shortened Midshaft Clavicular Fractures in Adolescents? J. Pediatr. Orthop. 2017, 37, 227–233.
42. Odorizzi, M.; Fitzgerald, M.; Gonzalez, J.; Giunchi, D.; Hamitaga, F.; De Rosa, V. Posttraumatic Pseudoarthrosis of a Clavicle Fracture in an 11-Year-Old Girl: A Case Report and Analysis.. Case Reports in Orthopedics 2020, 2020, 4069431-5.
43. Da Costa, J.C. Modern Surgery - Chapter 34. Bandages; W.B. Saunders: Philadelphia, PA, USA, 1903; 11.
44. Dzupa, V.; Bartonicek, J.; Zidka, M. Fracture of the clavicle after surgical treatment for congenital pseudarthrosis. Med Sci Monit 2004, 10.
45. Pennock, A.T.; Edmonds, E.W.; Bae, D.S.; Kocher, M.S.; Li, Y.; Farley, F.A.; Ellis, H.B.; Wilson, P.L.; Nepple, J.; Gordon, J.E.; et al. Adolescent clavicle nonunions: Potential risk factors and surgical management. J. Shoulder Elb. Surg. 2018, 27, 29–35.
46. Kubiak, R.; Slongo, T. Operative treatment of clavicle fractures in children: A review of 21 years. J. Pediatr. Orthop. 2002, 22, 736–739.