Traumatic plastic deformation of the tibia: case report and literature review

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ABSTRACT

Plastic deformation refers to the deformation of a bone, without fracture of its cortices, that persists once the deforming force has been removed. It is not a common condition but is seen more frequently in children than in adults. Of the cases published, there have been only three previous reports of tibial involvement, with the forearm being the most commonly affected site. We describe the case of a 10-year-old girl who, after falling down a slope, came to a sudden stop when her right foot hit a rock. This resulted in a fracture of the fibula and bowing of the tibia. We discuss the dilemmas faced in treatment and recommend regular follow up until the patient reaches skeletal maturity.

KEYWORDS

Plastic deformation – Tibia – Pediatric – Trauma

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Plastic deformation refers to the deformation of a bone, without fracture of its cortices, that persists once the deforming force has been removed.¹ It was first described clinically by Borden in 1974.² Since then, it has been reported most commonly in the forearm, with 58 of a review of 74 cases involving the forearm.³ The condition is rarely seen in the tibia. The same review also described the first case in the tibia and there have only been two subsequent reports.^{4,5} Our description provides a further example of this rare injury and reviews the literature, including details on the mechanism, management and possible outcome.

Case History

A 10-year-old girl presented with an isolated injury to her right leg. This was sustained when she slid down a slope, stopping suddenly when her right foot hit a rock. She had no past medical history and was not taking any regular medication. Physical examination revealed pain and moderate swelling over the lateral aspect of the leg. The initial plain film x-ray (Fig 1) showed a valgus fracture of the mid-shaft of the fibula and a valgus plastic deformity of the tibia.

Following advice from a paediatric orthopaedic specialist, the patient was managed without bearing weight and with a wedged below knee cast that did not change the angle of deformity. After four weeks, she was placed in a Sarmiento cast and allowed to bear weight. Eight weeks after the injury, the fractures were clinically united (non-tender and able to bear weight without pain) so the cast was removed and she was allowed to fully bear weight. The fibula fracture showed callus formation but a residual deformity of the

tibia of 7° compared to the left side (Fig 2). There was, however, no clinical deformity (Fig 3). The patient has returned to full activities with no problems but it is not yet known whether the deformity will remain at skeletal maturity. Figure 4 shows that x-rays revealed no change in the angle of deformation at almost two years after the injury.

Discussion

In studies carried out on dog ulnas, Chamay identified a stress-strain curve that demonstrates the relationship of

Figure 1 Initial anteroposterior (left) and lateral x-rays showing valgus plastic deformation of the tibia and a valgus fracture of the mid-shaft of the fibula

Figure 2 X-rays at eight weeks after the injury demonstrating a callus at the fibula fracture and a residual valgus deformity of the tibia of 7° (left) compared to the uninjured side

Figure 3 Photograph taken at six weeks after the injury showing no clinical deformity

Figure 4 Anteroposterior (left) and lateral x-rays taken at 22 months after the injury

applied force to deformation.⁶ He applied a longitudinal compression force to the curved ulna, which therefore deformed. At forces of lower magnitude, the bone returned to its original shape and length on removing the force (elastic deformation). Once the elastic limit of bone was reached there was a period where permanent deformation would occur (plastic deformation). Fracture of the bone eventually occurred if the force was increased further. Histologically, plastic deformation is a combination of compressive deformities on the concave side of the bone and tensile deformities on the convex side.

Though not common, plastic deformation of bone is seen much more frequently in children than in adults. A study testing femoral cortical bone from subjects between 2 and 48 years of age found that children's bones have a greater ability to undergo plastic deformation and absorb more energy before breaking, probably due to a lower ash content.⁷ This explains the higher incidence of plastic deformation injuries in children.

It has been hypothesised that the relatively high incidence of plastic deformation in the forearm is due to the high frequency of trauma to the forearm in children, the presence of two naturally curved bones of similar diameter and a wide zone in the bones of the forearm of plastic deformation before fracture.² The tibia is therefore less likely to be affected as there is no intrinsic curvature.^{4,8} One of the previous cases of tibial plastic deformation was caused through a fulcrum-like mechanism.⁴ Another case report, along with ours, describes a longitudinal compressive force.⁵ It is difficult to explain how true longitudinal compression of a straight bone could result in plastic deformation.

Our patient had a valgus plastic deformation of 7°. In order to reduce this deformity, the force necessary would be the same as that required to produce the deformity, likely to be 100–150% of the patient's weight.⁸ This is most easily achieved over a fulcrum,⁹ which has produced reasonable results in the forearm. Since the exact mechanism of plastic deformation in the tibia is unclear (as explained above), whether this means of reduction would be effective is unknown and has not been reported. It was therefore not attempted in our case.

Although there is evidence of remodelling of plastic deformation in younger children, less occurs in older children.⁸ There was no apparent remodelling in a 12-year-old with plastic deformation of the tibia.⁴ Our patient's valgus deformity is therefore unlikely to change significantly and may predispose her to osteoarthritis of the knee and/or ankle.^{10,11} Consequently, it has been suggested that residual deformities of more than 10° may require surgical treatment if clinically symptomatic with ankle or knee pain.¹² We plan to follow this patient up annually until she reaches skeletal maturity.

Conclusions

Plastic deformation of the tibia is a rare condition, the exact causative mechanism of which is unknown. This case illustrates the dilemma of whether to attempt a reduction that is unlikely to be achieved or leave the patient with a

residual deformity that may predispose her to osteoarthritis or fracture.

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