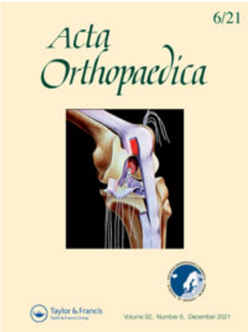

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THE SKIERS' BOOT TOP FRACTURE

Rising Incidence, Characteristics, Treatment

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Among the bony injuries sustained as a result of skiing accidents fractures of the tibio-fibular complex predominate. These fractures may vary considerably as to their localization, the form and extension of the fracture line, and the degree of displacement. They may be located in the ankle region or they may affect the tibial shaft or the region of the knee. Of the ankle injuries, the simple fracture of the external malleolus with a spiral fracture line beginning at the level of the ankle joint and extending cephalad and laterally is met so often in skiers that it is sometimes called "the ski fracture" (*Bätzner* 1957, *Moritz* 1959, *Ellison, Carroll, Haddon & Wolf* 1962, *Spademan* 1968). The "Bosworth" fracture in which the proximal fragment of the fibula becomes impacted with its distal end behind the posterolateral ridge of the tibia (*Bosworth* 1947) is also held to be more or less characteristic for skiers. This latter fracture is, however, seen less often and so are fractures of the tibial malleolus and bimalleolar fractures. All these bony injuries in the ankle region, of course, result from a sudden thrust of the talus against the malleoli. Although they are often seen in skiers, they are in no way exclusive to the sport, but are also met as a result of a variety of other activities.

The tibial shaft fractures, met in skiers, may be divided into spiral and transverse fractures, the fracture line reflecting the direction of the forces causing the injury. Spiral fractures of the tibio-fibular complex, which are sometimes comminuted with "butterfly" fragments, occur as the result of the same rotational force also responsible for the majority of ankle injuries. Such forces are likely to arise during down-hill skiing when the skier for some reason or other is unable to complete a turn and falls in the direction of his original motion. The reason why these forces sometimes result in tibial shaft fractures and at other occasions in ankle fractures is not clear, but Erskine (1959) postulates that spiral fractures of the tibial shaft tend to arise at high speeds whereas lower speed accidents are more likely to result in fractures of the ankle region.

Transverse fractures, on the other hand, have a very different aetiology. Sometimes these fractures occur as a result of a force directly striking the lower extremity, usually in the direction of its motion. More often they occur when the forward motion of the skier is abruptly slowed or stopped, for instance, by his skis suddenly running into soft snow. The skier then falls forward and if his heels are firmly fixed to the skis a transverse fracture may occur at the level of the top of the ski boot. The occurrence of these "boot top" fractures has been noted in a number of studies (*Moritz* 1962, *Westlin* 1966, *Spademan* 1968). Little attention has, however, been paid to the characteristic features of this fracture.

In the present paper the boot top fractures admitted during the last 2.5 years to the hospital of Östersund are studied. This hospital is the only hospital in the county of Jämtland, where Swedish down-hill skiing is mainly concentrated. The typical pattern of deformity found in the boot top fracture is described and an account is given of a simple method which enables the surgeon to reduce the fracture by manipulation.

INCIDENCE

In order to estimate the relative incidence of low transverse tibial fractures, all tibial shaft fractures treated at the hospital during the period 1 January 1966–1 June 1968 were studied. As there was an impression that this incidence had increased during recent years, tibial shaft fractures treated between 1 January 1956 and 1 June 1958 were also reviewed. The tibial shaft fractures, not engaging either the knee or the ankle, which were due to ski injuries, were divided into two groups, one group comprising transverse fractures within 10 cm of the ankle joint, and another group with all the other fractures. With very few exceptions, due to collisions, this latter group consisted of spiral fractures.

Table 1 gives the numbers of low transverse and of spiral and other fractures due to ski injuries. As seen in this Table there were only a few low transverse fractures during the first period studied. Ten years later their incidence had increased sharply. This increase was more pronounced than that of the other fractures due to ski injuries. The difference between the two period is probably significant (χ^2 = 4.46; d.f. = 1; $0.05 > P > 0.01$).

Table 1. Skiers' tibial shaft fractures treated during two periods

Period	1956–58	1966–68	
Type of fracture			
Low transverse	4	32	36
Spiral and other	36	82	118
	40	114	154

CASE HISTORY

Although a number of patients were very uncertain about their speed and the snow conditions at the moment of the injury and many had great difficulty in remembering how they had fallen, the typical case history seemed to be as follows: A boy or young adult—only 6 of the 32 patients were 18 years or older; 13 were 12–14 years old—often with considerable training and equipped with high, hard leather ski boots is more or less rapidly skiing straight down a slope. His boots are fastened to the skis with "long thong" straps, "kandahar" bindings, or with a simple form of safety bindings, which only release at rotatory stress i.e. rotation in the plane of the boot bottoms. When suddenly his skis meet an obstacle, his forward motion is abruptly stopped, the patient falls forward and is unable to stand afterwards. Only one patient with a boot top fracture had safety bindings with a device enabling release also with a straight forward stress, which actually disengaged at the time of the accident.

RADIOLOGICAL CHARACTERISTICS

The radiological features are summarized in Table 2. As seen in this Table the length of the distal fragment, measured as the distance between the fracture line and the ankle joint, was in most cases less than 6 cm.

Backward angulation was found in all but 5 cases. This angulation was only slightly indicated ($< 5°$) in 5 cases; in the others it was more strongly marked, e.g. in 13 cases it was more than 15°. In more than half of the cases there was some forward displacement of the distal fragment. As a rule this forward displacement measured less than 1 cm.

In many of these young patients there was only slight angulation, the fracture having the characteristics of a greenstick fracture. Finally in all cases but two both the tibia and the fibula were fractured. Figures 1 and 2 show the radiological findings in a 15-year-old boy.

Table 2. Radiological findings in 32 boot top fractures

Lateral projection			Frontal projection		
	Angulation	Displacement Distal fragment		Angulation	Displacement Distal fragment
Forward	0	18	Medial	4	6
Backward	27	0	Lateral	3	3
None	5	14	None	25	23

Length of distal fragment

	<3,	3–3.9,	4–4.9,	5–5.9,	6–6.9,	7–7.9,	8–8.9,	9–9.9 cm
Number	6	5	8	6	2	3	0	2

Figure 1. Boot top fracture in 15-year-old boy. Typical backward angulation. Forward displacement of distal fragment only slightly indicated.

Figure 2. Same case. Frontal projection.

TREATMENT

Attempts to reduce fractures with the typical deformity were made under TV fluoroscopy control so that every movement in the fracture could be followed. These attempts showed that reduction in many cases was surprisingly easy if the surgeon tried to push and tilt the distal fragment backwards by taking a steady grip on the foot, held in extreme plantar flexion. Therefore reduction with the foot in plantar flexion, performed in general anaesthesia, became the method of choice for the treatment of these fractures. In order to prevent redisplacement—the fracture often seemed inclined to slip back into its original position—a whole leg plaster was then applied, as a rule also with the foot in moderate plantar flexion. This was maintained during at least one month, in some cases even 2–4 weeks longer. After this a new plaster with the foot in the neutral position was usually given.

With the exception of two cases in which methods of internal fixation were applied by way of trial, all the other cases with a deformity were subjected to this method of manipulative reduction. In three cases, one of which was severely comminuted, the method failed. In all the others satisfactory reduction was accomplished.

Figure 3. Boot top fracture in 12-year-old boy. Slight backward angulation. Moderate forward displacement of the distal fragment. The foot is held in plantar flexion to facilitate reduction.

Figure 4. Same case after reduction and immobilization with the foot in plantar flexion.

Immobilization with the foot in plantar flexion during one month or even longer did not seem to have any ill effect on the joints of these young people. The reduction in the mobility of the foot tended to disappear soon.

Figure 3 shows a boot top fracture with the typical deformity in a 12-year-old boy. The foot is held in plantar flexion after which the fracture is easily reduced (see Figure 4).

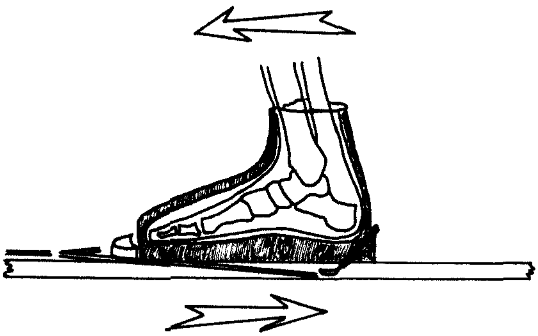
DISCUSSION

A number of factors may be responsible for the relative increase among skiers of low transverse tibial fractures as compared with spiral fractures. There is, for instance, the increasing popularity of downhill skiing which, at least in Sweden, more and more tends to replace touring and cross-country skiing. Further, as a snugly fitting boot facilitates the transmission of every motion of the foot to the ski, which is a prerequisite for its proper control, ski boot manufacturers tend to make the boots ever harder and tighter, e.g. by strengthening the leather with a built-in lacing. This, of course, results in a very hard boot top, which does not easily yield to pressure. It is also possible that, with ski slopes becoming more and more crowded, there is a stronger tendency to the formation of ruts and so-called moguls (*McIntyre* 1963), i.e. small mounds of snow in which the ski point may get trapped. The relative importance of these factors is, of course, difficult to ascertain.

The analysis of the cases of boot top fractures treated at our hospital during the last 2.5 years showed that not only is there a typical case history but there also is a typical radiological deformity consisting of backward angulation and some forward displacement of the distal fragment. Although boot top fractures are occasionally mentioned in treatises on ski injuries, I found only one case with complete roentgenological details in the literature. It is of interest to note that, though in this case described by *Clayton* (1962) there also is some lateral angulation and comminution, the typical deformity can be very clearly seen.

As no muscles insert into the distal part of the tibia, nor arise from it, this deformity can not be alleged to muscular force. No doubt, the backward angulation has to be ascribed to the forces responsible for the fracture (see Figure 5). With the body in swift forward motion, the ski-boot-foot unit is suddenly halted by an obstacle. The skier,

Skier's forward motion



Ski-boot-foot unit meeting obstacle

Figure 5. Forces involved in boot top fracture.

falling forward, breaks his leg against the hard boot top. A backward angulation may arise when he continues his fall if the boot top does not then yield to the pressure. The forward displacement of the distal fragment, seen in a number of cases, is more difficult to explain. This displacement cannot be due to the forces responsible for the fracture. These forces would, instead, tend to drive the distal fragment backwards, a displacement seen in none of the 32 cases. It seems possible, however, that the displacement arises when the patient tries to stand up after the injury. With the small distal fragment tilted forward, the weight of the body may make the proximal fragment slide backwards in the fracture line.

The fact that the fracture showed a tendency, after reduction, to return to the original deformity is not at variance with its non-muscular origin. The same tendency is sometimes seen in other fractures in which muscular forces do not play a role, e.g. the simple Colles fracture of the radius. Because of this tendency we preferred to apply the plaster with the foot in plantar flexion. The question arises how the empirical observation that reduction was much easier to accomplish with the foot in plantar flexion is to be explained. Plantar flexion of the foot is halted by ligaments, i.e. the anterior part of the deltoid ligament and the anterior talo fibular ligament and by the posterior process of the talus thrusting against the tibia's back. It is possible that the pull of the ligaments on the front of the distal fragment and the thrust of the talus against its back tend to counteract its forward tilting. It seems even more important that with the foot in plantar flexion, the surgeon gets a better grip on the small distal fragment and that he obtains a lever which enables him to disimpact the fracture and to force the distal fragment back into position.

Finally, there is the important question if and how these injuries can be prevented. Studies by *Heinkel* (1958) and by *Haddon, Ellison & Carroll* (1962) have supplied convincing evidence of the efficacy of safety bindings. Such bindings should release not only with a rotatory but also with a straight forward stress. They should, furthermore, be properly adjusted, i.e. the threshold force needed for release should not be too great. Therefore they should also be kept free from wet snow which, when frozen to ice at higher altitudes, may prevent release.

The fact that only one of the patients studied here had effective safety bindings suggests that with such a simple improvement of the skier's equipment much can be achieved in the prophylaxis of the boot top fracture.

SUMMARY

A study is made of a series of low transverse fractures of the tibiofibular complex due to ski injuries. The incidence of these so-called "boot top" fractures is found to have increased as compared with other tibial shaft fractures in skiers. The typical case history is described and an analysis is made of the roentgenological characteristics of this type of fracture. From this analysis it appears that in typical cases of boot top injuries, there is a backward angulation in the fracture, often combined with a forward displacement of the distal fragment. A hypothesis to explain this typical deformity is presented. Finally, a method for the manipulative reduction of these fractures is described. According to this method the surgeon should force the small distal fragment backwards by taking a steady grip on the foot held in extreme plantar flexion. The fracture is then immobilized with the foot in moderate plantar flexion during at least one month after which a plaster cast is applied with the foot in the neutral position.

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