0198-0211/86/0703-0162$02.00/0
FOOT & ANKLE

Injuries to the Metatarsophalangeal Joints in Athletes

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ABSTRACT

Injury to the metatarsophalangeal joints in sports has become an increasing problem with the advent of more flexible shoewear and artificial playing surfaces. These injuries vary from mild sprains to severe tearing of the capsuloligamentous complex including avulsion fractures. This may include a compression fracture of the metatarsal head in the more severe cases. At the extreme, dislocation or fracture-dislocation of the metatarsophalangeal joint occurs. The findings in 62 cases of these injuries in Rice University athletes from 1971 to 1985 are presented. Treatment follows a standard regimen of ice, taping and anti-inflammatory medication with gradual return to sports activity as symptoms allow. Recommendations for preventive therapy include stiffening the forefoot in athletic shoes or the use of an orthotic device. This should reduce the incidence of long-term sequelae.

Traumatic injuries to the metatarsophalangeal (MP) joints occurring with sports participation have received little attention in the literature.[2–4] These injuries seem to be occurring with increasing frequency, and long-term consequences are becoming more evident.[3] This has been particularly true for a hyperextension injury to the first MP joint. It has become a relatively common problem among football players participating upon artificial playing surfaces, hence the designation "turf toe."[2] A similar mechanism can produce injury to the lesser MP joints as well. Frank dislocation or fracture-dislocation of the MP joints is relatively rare.[5] The wide spectrum of injury to these joints requires the treating physician to have a thorough understanding of the anatomy and biomechanics of the involved area. Appropriate treatment can then be based on proper classification of the injury, allowing the earliest safe return of the athlete to playing sports.

MATERIALS AND METHODS

In order to more effectively analyze this variety of injury, all available records of athletes participating in intercollegiate sports at Rice University between 1971 and 1985 were reviewed. From a total of 1063 athletes, there were 188 injuries to the foot severe enough to warrant treatment. There were 53 Rice University athletes who sustained 63 MP joint injuries (Table 1). Seven athletes had more than one injury episode to the same first MP joint and three injured the first MP joint in both feet. There were 56 isolated injuries to the first MP joint, one combination injury to the first through third MP joints, two injuries to the second and third MP joints, one to the second through fifth MP joints, and three isolated injuries to the fifth MP joint. The injury occurred by a hyperextension mechanism in 32 of these cases, by plantarflexion in two, and from a contusion in one; the mechanism of injury was unknown in 28 cases. For the 51 football players injured, all injuries occurred on synthetic turf. The two track athletes were injured on a Tartan synthetic-surface track. Radiographs were taken in 65 foot injuries and in 16 of the turf toe cases. Players with MP joint injuries missed an average of 6 days of athletic participation, but time loss varied from 0 to 56 days. The latter occurred in one patient who underwent surgery. It should be noted that there were many players during this same period who were seen and treated for minor injury to the MP joint region. Because they did not miss any practices or games or require ongoing treatment, they are not included in the above-mentioned statistics. Injury to the forefoot was the most commonly noted foot injury and ranked third behind ankle and knee injuries as the most common time-loss injury at Rice University.

ANATOMY AND BIOMECHANICS

One need only to examine the forces involved in walking and running to gain an appreciation for the complex interaction between anatomy and function

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TABLE 1
Metatarsophalangeal Joint Injuries in Rice University Athletes between 1971 and 1985

ase no.	Sport	Foot involved[a]	MP joint (s) involved	Injury mechanism	Playing surface	Date of injury	Playing time missed (days)	Treatment[b]	Radiological findings acute
1	Football	R	1st	Unknown	Astroturf	11-19-71	0	I, T, C	
2	Football	R	1st	Hyperextension	Astroturf	8-30-72	1	I, T, C	
3	Football	L	1st	Unknown	Astroturf	9-23-73	3	I, T, C	
4	Football	R	1st	Unknown	Astroturf	9-22-74	10	I, T, C	
		R	1st	Unknown	Astroturf	10-19-75	9	I, T, C	
5	Football	R	5th	Uknown	Astroturf	10-12-74	0	I, T, C	None
6	Football	R	1st	Unknown	Astroturf	8-23-75	5	I, T, C	
7	Football	R	1st	Unknown	Astroturf	10-19-75	3	I, T, C	
8	Football	R	1st	Hyperextension	Astroturf	10-25-75	56	I, T, C, inj., surgery	Avulsion fracture at first MT neck
9	Football	NR	1st	Unknown	Astroturf	11-15-75	3	I, T, C	
10	Football	R	1st	Unknown	Astroturf	3-20-76	0	I, T, C	
11	Football	L	1st	Hyperextension	Astroturf	8-18-76	1	I, T, C	
		L	1st	Hyperextension	Astroturf	8-17-77	2	I, T, C	
12	Football	L	1st	Unknown	Astroturf	8-21-76	5	I, T, C	
13	Football	L	5th	Unknown	Astroturf	9-02-76	3	I, T, C	
14	Football	L	1st	Hyperextension	Astroturf	9-18-76	7	I, T, C	None
		R	1st	Hyperextension	Astroturf	11-03-76	0	I, T, C	Small spur on dorsal aspect of proximal phalanx
15	Football	L	1st	Hyperextension	Astroturf	9-29-76	6	I, T, C, inj.	
16	Football	L	1st	Unknown	Astroturf	11-14-76	0	I, T, C	
17	Football	R	1st	Hyperextension	Astroturf	3-31-77	3	I, T, C, S	None
18	Football	R	1st	Unknown	Astroturf	9-12-77	3	I, T, C	
		R	1st	Unknown	Astroturf	9-17-77	14	I, T, C, M	
19	Football	R	1st	Unknown	Astroturf	10-20-77	2	I, T, C	
20	Football	R	1st	Hyperextension	Astroturf	11-14-77	14	I, T, C, M	Small divot in first MT head and phalangeal base chip fracture
		R	1st	Hyperextension	Astroturf	9-11-78	8	I, T, C, M, O	
		L	1st	Hyperextension	Astroturf	9-09-80	0	I, T, C, M	
21	Football	L	1st	Unknown	Astroturf	9-03-78	1	I, T, C, M	
22	Football	L	1st	Unknown	Astroturf	9-19-78	6	I, T, C, M	
23	Football	L	1st	Unknown	Astroturf	9-20-78	1	I, T, C, M	
24	Football	L	1st	Hyperextension	Astroturf	11-15-78	3	I, T, C, M	
25	Football	R	1st	Unknown	Astroturf	9-29-79	2	I, T, C, M	
		R	1st	Unknown	Astroturf	10-20-80	0	I, T, C, M	
26	Football	R	2nd–3rd	Unknown	Astroturf	10-29-79	2	I, T, C, M	None
27	Football	L	2nd–5th	Unknown	Astroturf	9-23-80	0	I, T, C, M	
28	Football	L	1st	Hyperextension	Astroturf	10-06-80	5	I, T, C, M	None
29	Football	L	1st	Unknown	Astroturf	10-13-80	2	I, T, C, M	None
30	Football	R	1st	Hyperextension	Astroturf	3-12-81	6	I, T, C, M	
31	Football	R	1st	Unknown	Astroturf	8-30-81	1	I, T, C, M	
32	Football	R	1st	Hyperextension	Astroturf	9-02-81	5	I, T, C, M	
33	Football	R	1st–3rd	Contusion	Astroturf	10-14-81	4	I, T, C, M	
		R	1st	Hyperextension	Astroturf	11-06-83	3	I, T, C, M	
34	Football	B	1st	Hyperextension	Astroturf	10-21-81	0	I, T, C, M, S	
35	Football	R	1st	Unknown	Astroturf	11-07-81	0	I, T, C, M	Avulsion fracture at MP joint
36	Football	L	5th	Hyperextension	Astroturf	9-20-82	0	I, T, C, M	
37	Football	R	1st	Unknown	Astroturf	3-15-83	0	I, T, C, M	

TABLE 1 (continued)

Case no.	Sport	Foot involved[a]	MP joint (s) involved	Injury mechanism	Playing surface	Date of injury	Playing time missed (days)	Treatment[b]	Radiological findings acute
38	Football	R	1st	Hyperextension	Astroturf	3-24-83	15	I, T, C, M	Small cystic change in first MT head
		R	1st	Hyperextension	Astroturf	10-02-83	1	I, T, C, M	
39	Football	R	1st	Hyperextension	Astroturf	9-26-83	46	I, T, C, M	Mild HV, (HV angle = 22), slight dorsal and medial osteophyte formation
40	Football	L	1st	Hyperextension	Astroturf	10-15-83	9	I, T, C, M	
41	Football	L	1st	Hyperextension	Astroturf	9-04-84	1	I, T, C, M, O	
42	Football	L	1st	Unknown	Astroturf	10-07-84	0	I, T, C, M, O	
43	Football	R	1st	Hyperextension	Astroturf	10-21-84	43	I, T, C, M, inj., O	Small cystic change in first MT head
44	Football	R	1st	Hyperextension	Astroturf	11-11-84	0	I, T, C, M, O	
45	Track	R	1st	Plantarflexion	Tartan track	1-26-85	3	I, T, C, M, O	
46	Track	R	1st	Plantarflexion	Tartan track	2-12-85	6	I, T, C, M, O	
47	Football	R	1st	Hyperextension	Astroturf	3-10-85	2	I, T, C, M, O	
48	Football	L	1st	Hyperextension	Astroturf	3-12-85	20	I, T, C, M, O	
49	Football	L	1st	Hyperextension	Astroturf	8-31-85	0	I, T, C, M, O	None
50	Football	L	2nd-3rd	Unknown	Astroturf	9-03-85	0	I, T, C, M, O	
51	Football	L	1st	Hyperextension	Astroturf	9-06-85	0	I, T, C, M, O	None
52	Football	L	1st	Hyperextension	Astroturf	11-10-85	0	I, T, C, M, O	Flattened first MT head
53	Football	L	1st	Hyperextension	Astroturf	11-17-85	0	I, T, C, M, inj. O	Small dorsal chip fracture at MP joint

[a] R, right; L, left; NR, not recorded.

[b] I, ice; T, taping; C, contrast therapy; O, orthotic device; S, shoe change; M, nonsteroidal anti-inflammatory medication; inj., cortisone injection.

which exists in the forefoot.[12] Stability afforded by the bony configuration of these joints is enhanced by the capsuloligamentous complex (Fig. 1). Extrinsic and intrinsic musculotendinous structures form an intricate part of this complex and provide dynamic support to the joint as well as movement (Fig. 2).[14] The first MP joint is unique in having medial and lateral sesamoids within the two heads of the flexor hallucis brevis. These form a portion of the capsuloligamentous complex of the first MP joint and give it even greater stability. The anatomy of the lesser MP joints is similar to that of the first, but sesamoids occur with much less frequency. They are connected to the long flexor tendon or the intrinsics, but are present in less than 10% of normal feet.[14] The capsuloligamentous complex is intrinsic to the stability of the MP joints and serves to guide the joint through its range of motion. The medial and lateral portions of this complex, as best illustrated in the first MP joint, have two components (Fig. 3).[14] The MP ligament originates from the lateral tubercle on the metatarsal head and fans out to insert on a slightly broader area on the base of the proximal phalanx. The second component is the metatarsosesamoid or suspensory ligament. It also originates from the lateral tubercle but fans out in a more plantar direction to insert on the sesamoids and the plantar plate. This thickened fibrous plate is firmly anchored to the base of the proximal phalanx plantarly and attaches loosely through the capsule to the neck of the metatarsal. Due to the cam effect of the metatarsal head, various portions of this collateral ligament complex are under tension during different stages of the joint's range of motion. Giannikas et al.[8] have shown that the plantar portion of this capsuloligamentous complex is avulsed from the head and neck of the metatarsal by excessive hyperextension.

The more well developed nature of the structures surrounding the first MP joint reflects the greater stress placed upon this area of the forefoot. The great toe typically carries more than twice the load than the other toes,[13,15] and the maximum force acting across the joint is equal to 40% to 60% of body weight.[10,15] During

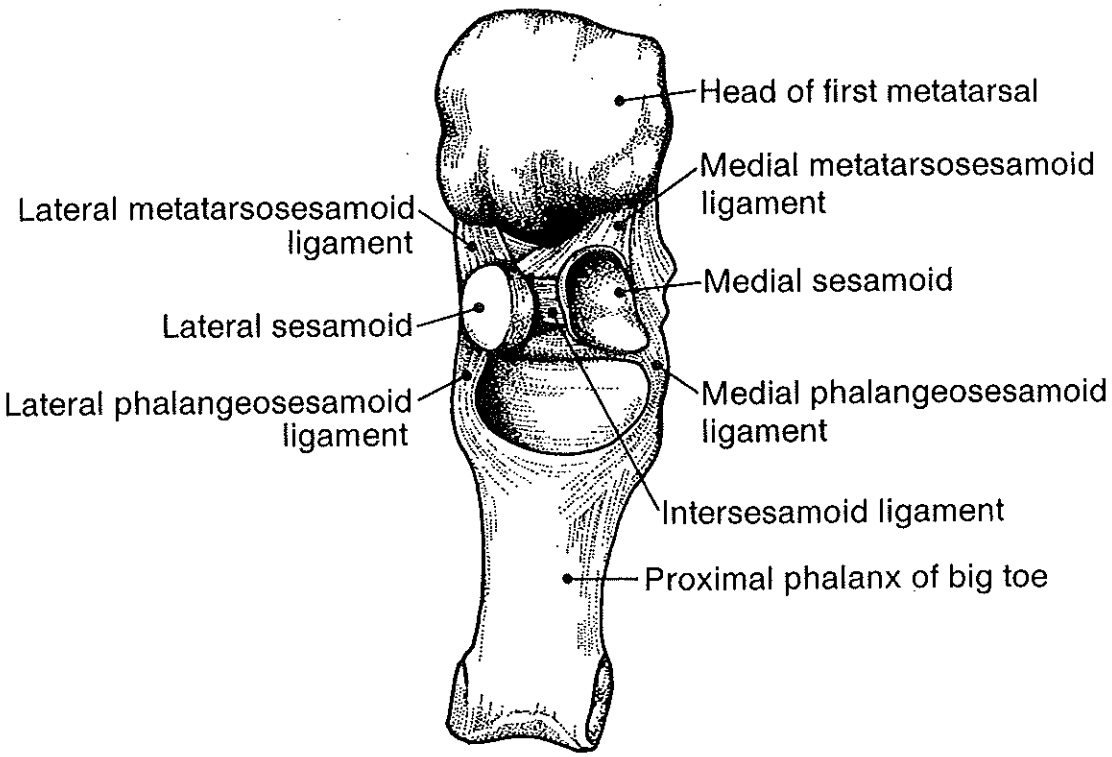

Fig. 1. Diagrammatic representation of capsuloligamentous complex of first MP joint. (Redrawn after Gillette: Des os sesamoides. Anat. Physiol. Normal Path., 8:506, 1872.)

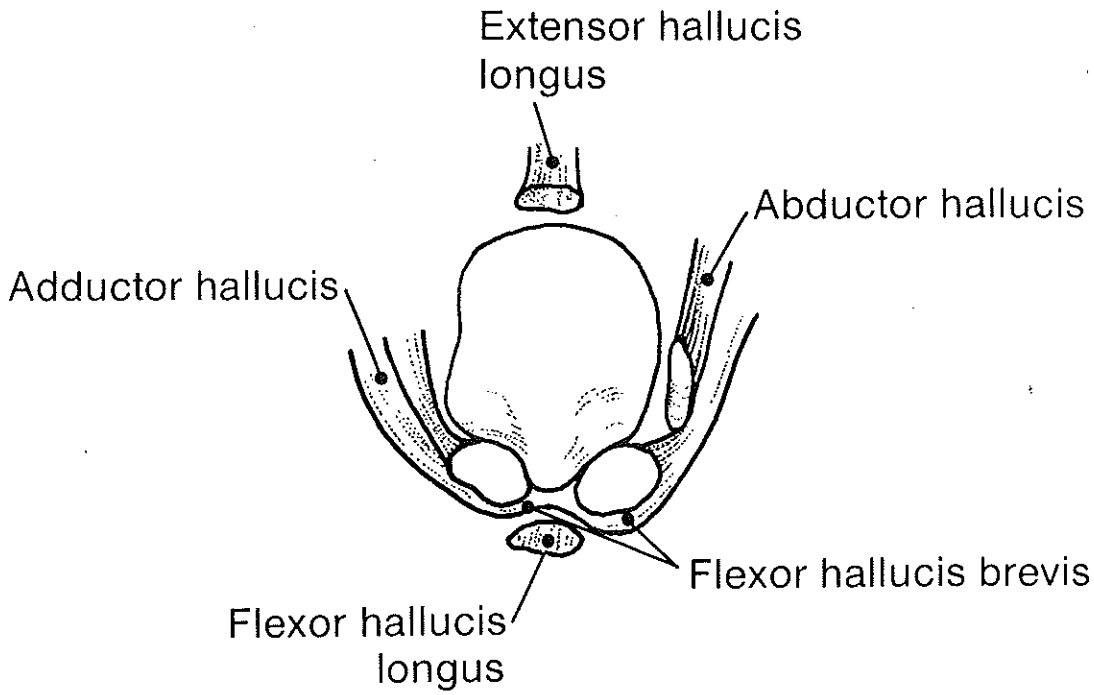

Fig. 2. Diagrammatic representation of musculotendinous support of first MP joint. (Redrawn by permission from Mann, R.A., and Coughlin, M.J.: Hallux valgus and complications of hallus valgus. *In* Surgery of the foot, 5th Ed. Mann, R.A. (ed.), St. Louis, C.V. Mosby, 1986, p. 66.)

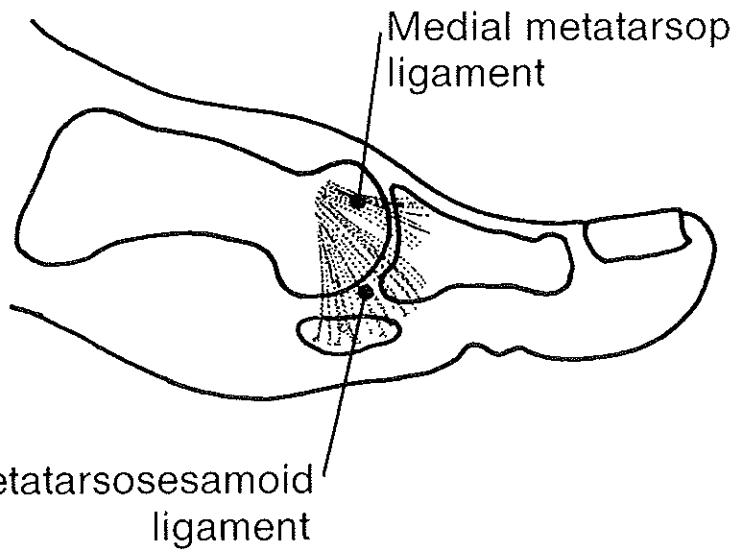

Fig. 3. Diagrammatic representation of the two components of the collateral ligament complex of the first MP joint.

jogging and running, peak forces can be increased by two or three times.[12]

Sammarco[13] has shown that instant centers of motion for this joint fall within the metatarsal head. As in other diarthrodial joints, motion occurs between the metatarsal head and the proximal phalanx by a sliding action at the joint surface. In full extension this sliding action gives way to compression of the dorsal articular surfaces of the metatarsal head and proximal phalanx. Normal active range of motion in the first MP joint is approximately 80 degrees with an additional 25 degrees of passive motion available.[11] This varies somewhat with age. At least 60 degrees of dorsiflexion is considered normal in barefoot walking on level surfaces.[1,10] Shoewear with stiff soles can restrict MP joint dorsiflexion to 25 to 30 degrees without affecting the gait pattern noticeably.[1]

CLASSIFICATION OF INJURIES

Injuries to the MP joints occur from a variety of mechanisms to produce a sprain, dislocation, or fracture-dislocation. The most common mechanism is hyperextension, and this is the classical situation producing the turf toe injury.[2,3] Various amounts of valgus stress are frequently involved and change the pathological character of the injury to some degree. A much less frequent mechanism is hyperflexion. Coker et al.[3] have illustrated the different injuries with situations arising among football players, and this has correlated well with our experience at Rice University.

Classification of injury to the MP joints can be performed from the extent of injury and the patient's response to treatment. Although this applies principally to the first MP joint injuries, it can be used for the lesser MP joints also. Sprains involving the capsuloligamentous complex are most common and fall into three stages. Grade 1 sprains have localized tenderness either plantar or medial with minimal, if any, swelling and no ecchymosis. Players with this injury continue to participate in their sport. Pathology involves stretching of the capsuloligamentous complex. Grade 2 sprains have more diffuse tenderness with mild to moderate swelling and ecchymosis. There is pain and usually some restriction in range of motion. Time loss from sport varies from 1 day to 2 weeks. The capsuloligamentous complex is partially torn, but there is no articular injury. Grade 3 sprains to the MP joint have severe tenderness to palpation which, although diffuse, is maximal dorsally. There is always considerable swelling and ecchymosis combined with marked restriction in joint motion (Fig. 4, A and B). Athletes may miss 3 to 6 weeks with this injury. It is the authors' feeling that this injury, in addition to tearing the capsuloligamentous complex, produces a compression injury to the articular cartilage and underlying bone on the metatarsal head. Routine radiographs were taken in 17 patients (18 feet) MP joint injuries. The majority of these have been negative, but useful information is occasionally obtained. Several athletes have had small flecks of bone about the MP joint, which probably represent capsuloligamentous avulsions or osteochondral fragments produced by the compression injury (Fig. 5, A and B). Other findings have also been noted. Two radiographs revealed a cystic change in the first metatarsal head (Fig. 6), and another had a divot on the metatarsal head associated with a dorsal fracture off the base of the proximal phalanx (Fig. 7).

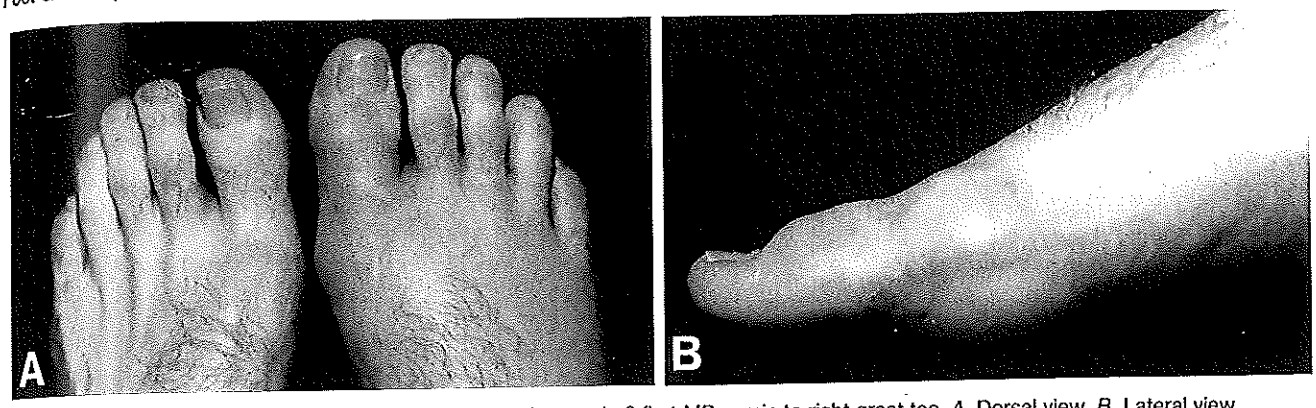

Fig. 4. Clinical photograph taken 48 hours following grade 3 first MP sprain to right great toe. *A*, Dorsal view. *B*, Lateral view.

Although the grade 3 sprains may represent a spontaneously reduced dislocation of the MP joint, frank dislocations do occur (Fig. 8, A–C). These are dorsal in location and may be either simple or complex. Diagnosis is made obvious from the deformity present. Radiographs are essential to rule out any associated fracture. In the athletic setting, reductions are usually attempted acutely by the trainer or team physician. This should be performed by hyperextension of the MP joint, longitudinal traction, and manipulation to the reduced position by plantar-directed pressure on the base of the proximal phalanx.[5] Radiographs should be taken following reduction to demonstrate the presence of any fracture and to confirm the restoration of normal anatomic alignment. At least 4 to 6 weeks are usually required before return to competition.

Irreducible dislocations of the MP joints are relatively rare.[5] These generally cannot be distinguished clinically or radiographically from simple dislocations, although DeLee[5] suggsts that a medial skin dimple is often associated with irreducibility by closed means. The pathology involves "buttonholing" of the metatarsal head through the plantar capsule with interposition of the plantar plate between the base of the proximal phalanx and the metatarsal head. The metatarsal head becomes entrapped by the medial head of the flexor hallucis brevis and abductor hallucis medially and the lateral head of the flexor hallucis brevis and the adductor hallucis laterally. Dorsal and plantar approaches to surgical treatment have been described.[5,8] The authors have seen only two MP joint dislocations occurring in athletes. One involved a semiprofessional quarterback with dorsal dislocation of the first through third MP joints. The second and third MP joints reduced easily, but the first was a Jahss type I dislocation[9] which required an open reduction. The second case occurred in a city-league basketball player who had a Jahss type IIB dislocation[9] of the first MP joint (Fig. 9 A–D). It reduced closed but was treated with excision of the medial sesamoid and repair of the capsular defect.

TREATMENT

Once an MP joint injury occurs, treatment follows standard guidelines with ice, compression, and rest followed by contrast and joint mobilization. Since 1977, a nonsteroidal antiinflammatory medicine (ibuprofen, 400 to 600 mg three times a day) has been prescribed for all players with this injury. Once the player is sufficiently comfortable to resume play, he is protected by a combination of taping similar to that described by Cooper and Fair[4] and the use of a stiffer shoe or orthotic device. Recently we have had success with a custom-made orthotic device taken from a mold of the foot (Fig. 10, A and B). It seems to be more comfortable and limits excessive dorsiflexion more effectively than the orthosis incorporating the spring steel plate. In the past we have occasionally treated these MP joint sprains with an injection of 2 ml of an anesthetic agent (lidocaine 2% without epinephrine or bupivacaine 0.25% without epinephrine) and 1 ml of a cortisone preparation (methylprednisolone or dexamethasone acetate suspension). This was done in an effort to allow a symptomatic athlete to continue sports participation in the face of what was felt to be a relatively minor injury. It appeared that this led to aggravation of the injury in at least two of the four instances where it was performed. We currently feel that injections are contraindicated for this condition.

DISCUSSION

Analysis of the foot injuries in the intercollegiate athletes at Rice University has clearly shown that the MP joint is a vulnerable area. This is particularly true for the first MP joint which was involved in over 80%

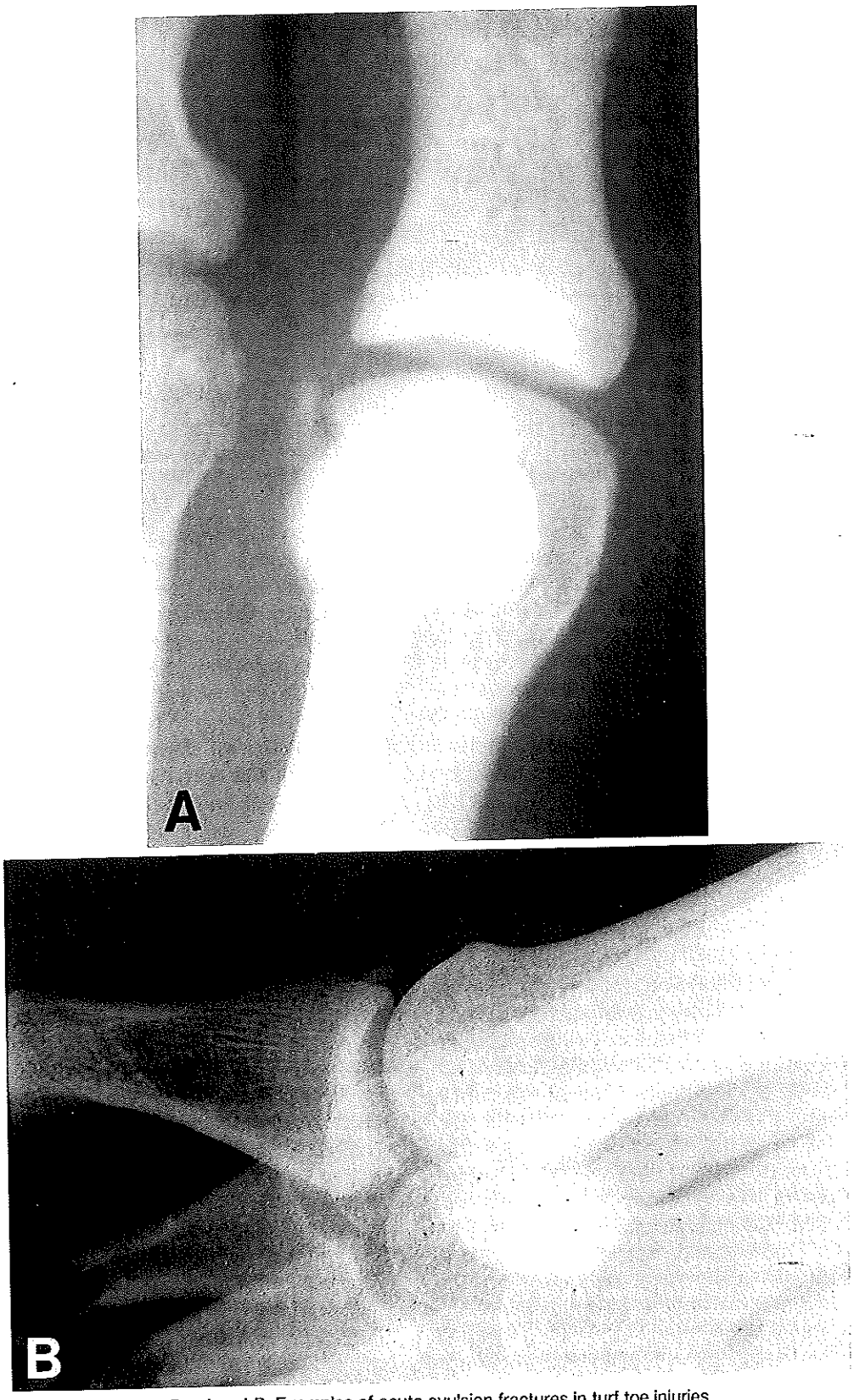

Fig. 5. *A* and *B*, Examples of acute avulsion fractures in turf toe injuries.

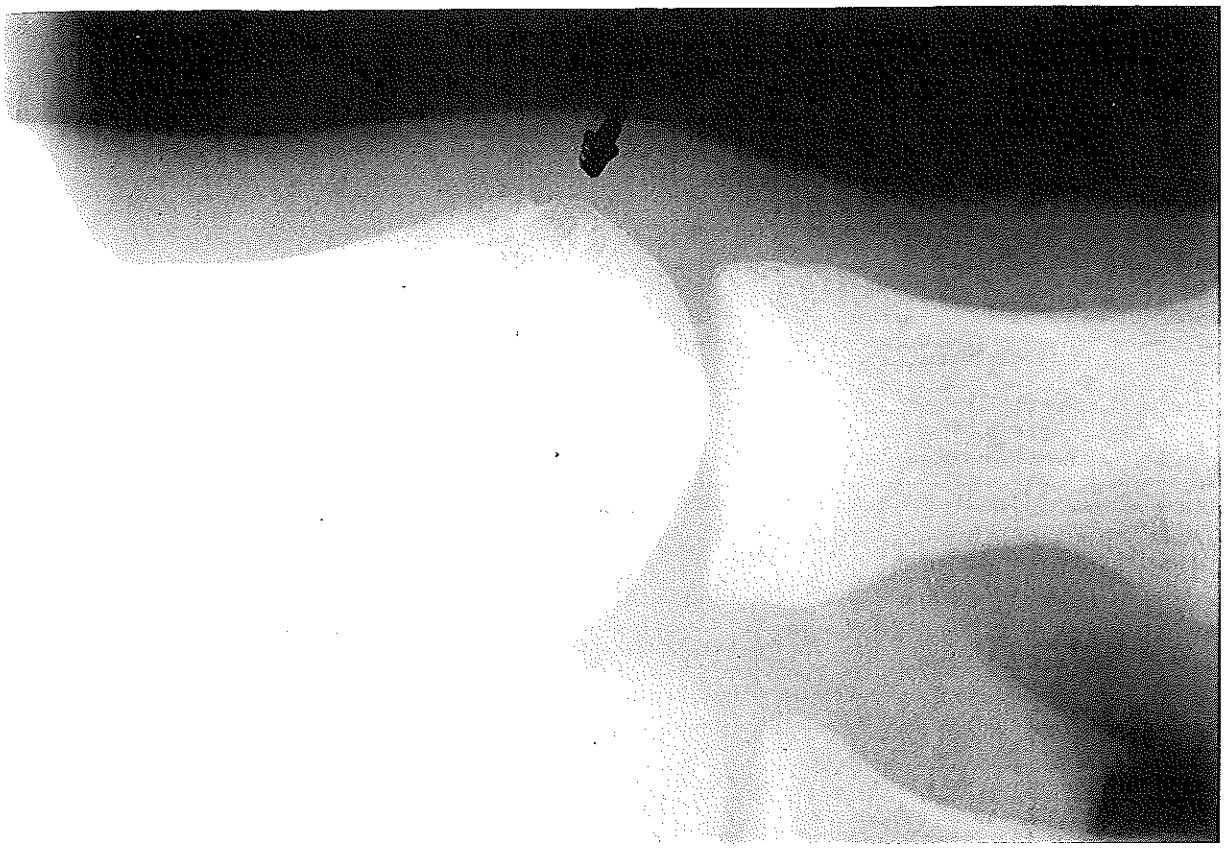

Fig. 6. Cyst-like change in first MT head seen after grade 3 first MP sprain.

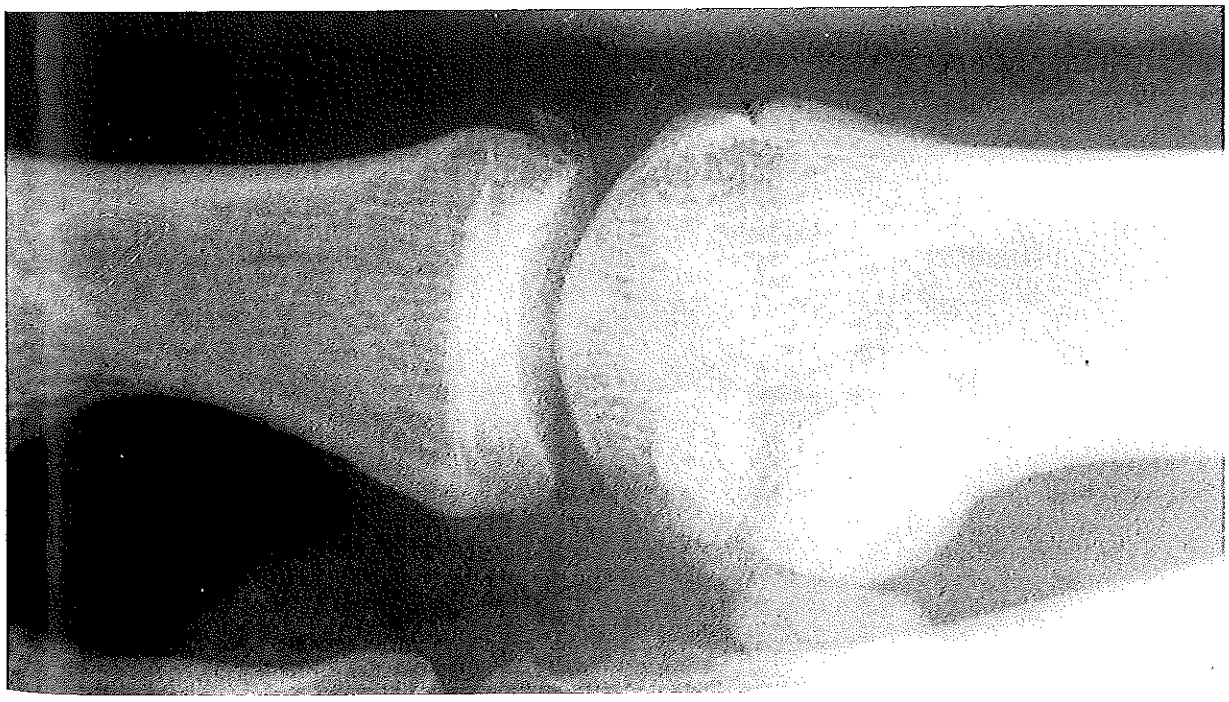

Fig. 7. Divot in dorsomedial first MT head together with avulsion fracture of proximal phalangeal base following turf toe injury.

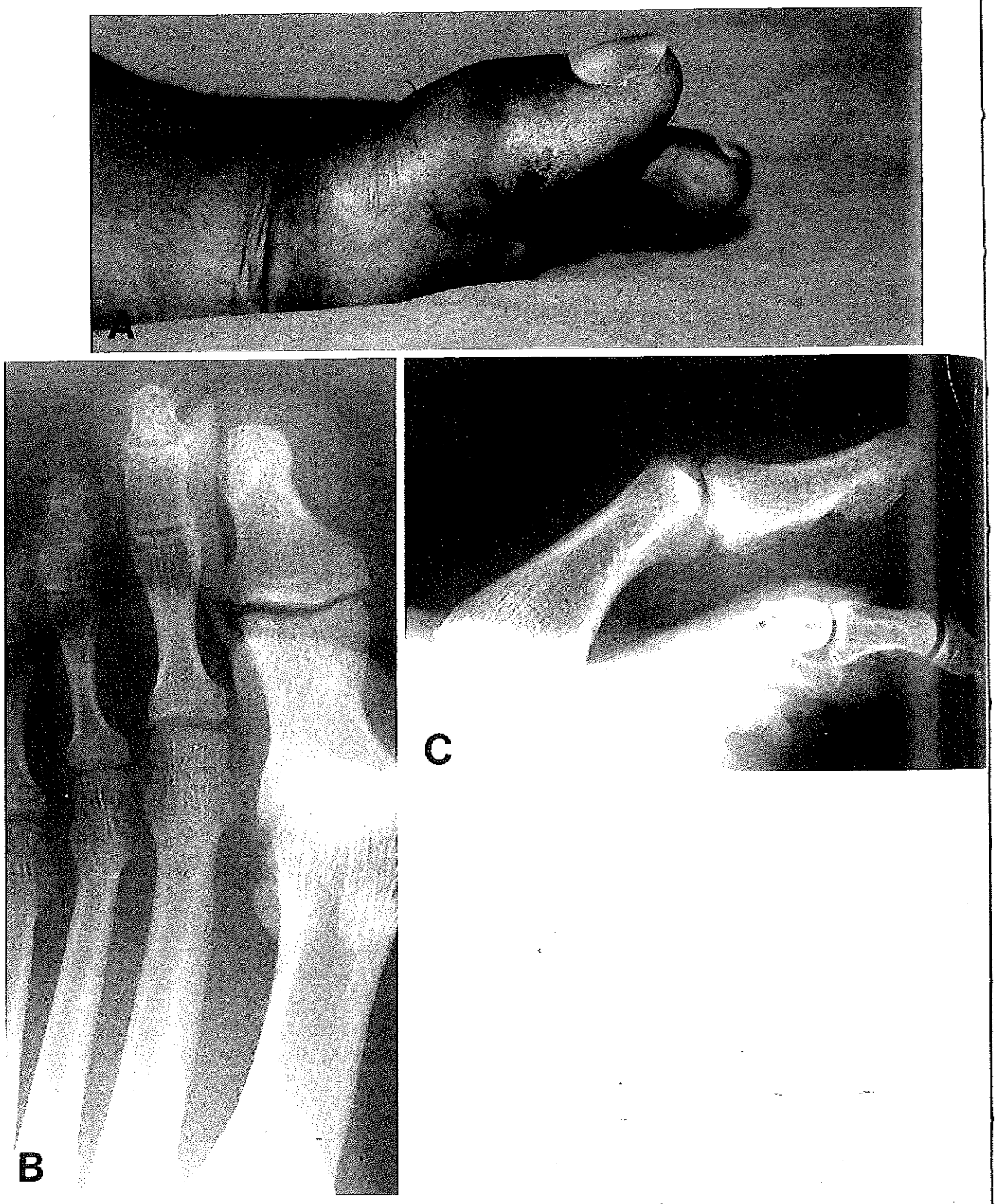

Fig. 8. Jahss type I dislocation of first MP joint. *A*, Clinical photograph. *B*, AP radiograph. *C*, Lateral radiograph.

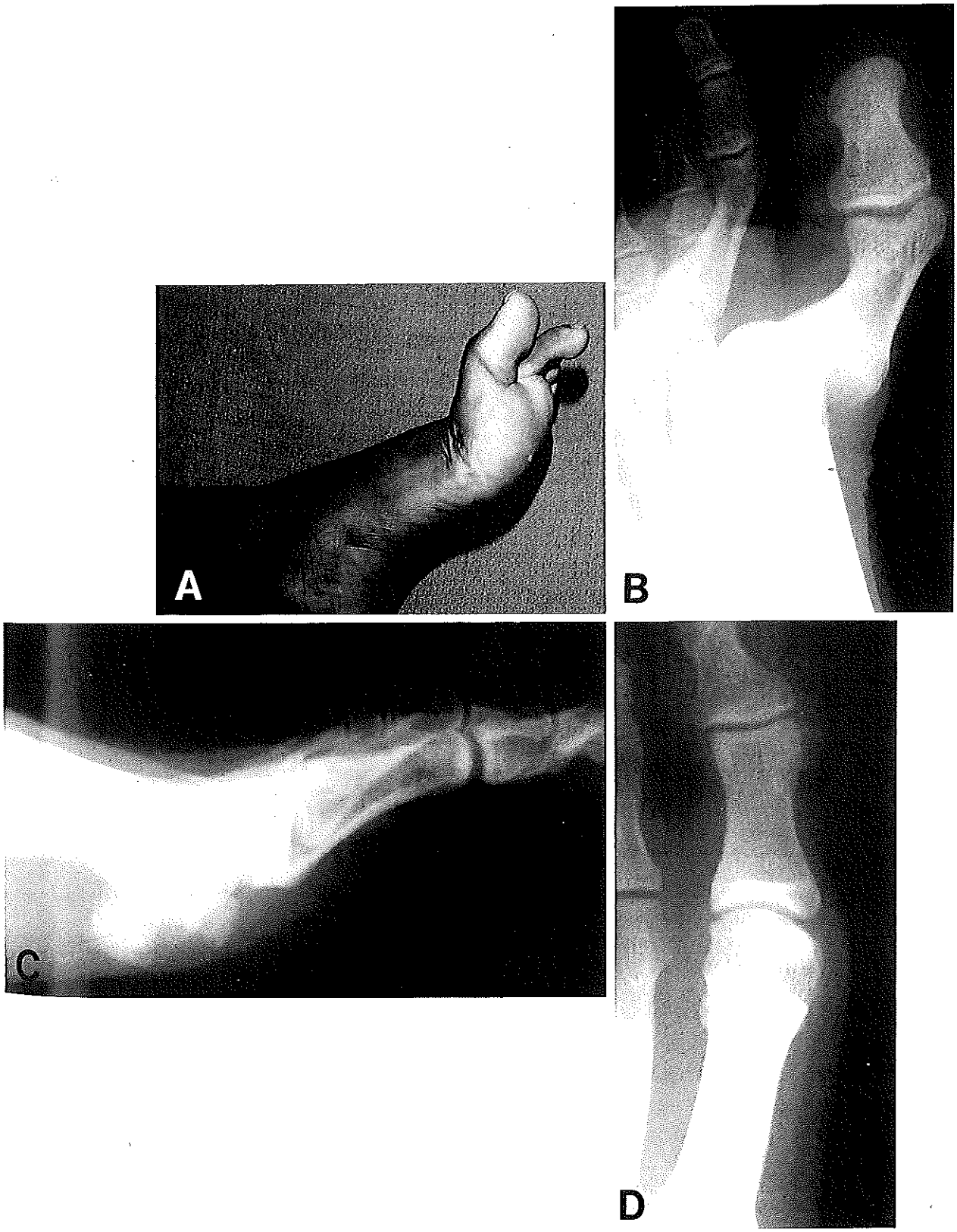

Fig. 9. Jahss type IIB dislocation of first MP joint. *A*, Clinical photograph. *B*, Prereduction radiograph. *C*, Postreduction lateral radiograph. *D*, Postreduction preoperative AP radiograph prior to excision demonstrating wide separation of medial sesamoid fracture fragments.

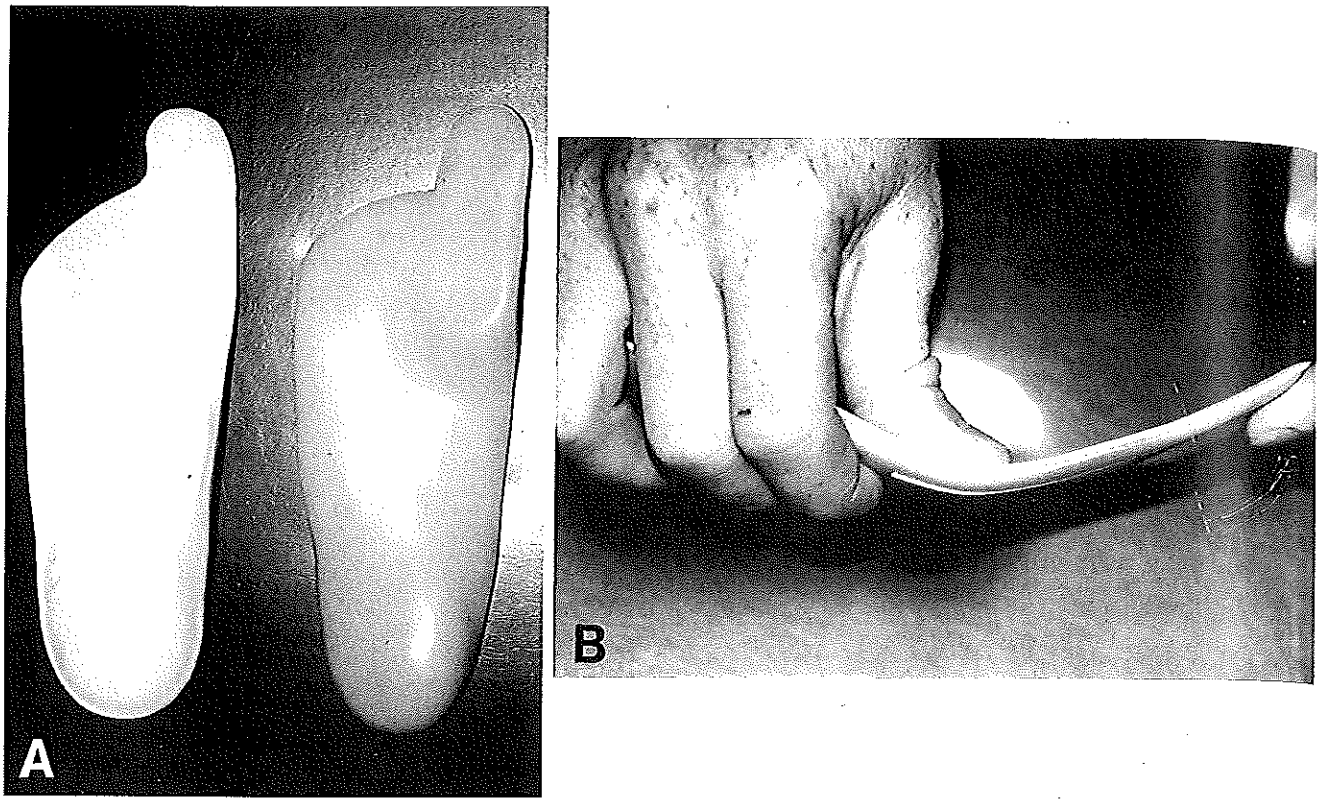

Fig. 10. Example of custom-made orthotic device. *A*, Dorsal and plantar view of orthosis. *B*, Demonstration of stiffness of orthosis limiting first MP dorsiflexion.

of our cases. This injury corresponds to the classical turf toe described by Bowers and Martin.[2] In 1975, attention was initially focused on the increasing incidence of this injury related to the introduction of synthetic playing surfaces.[7] Since then, several authors[2,3,4,17] have reiterated that relationship and described it as a shoe-surface phenomenon. Since athletes often choose their shoewear for psychological reasons with no regard to support of the foot,[6,16] the use of lightweight, flexible shoes on artificial turf has apparently compounded the problem. The trainers and team physicians working at Rice University during the past 25 years cannot recall a single instance of a severe MP joint sprain occurring in a football player wearing the traditional cleated shoe for use on grass. This is not surprising since a steel plate is incorporated into the sole to allow attachment of the cleats, and this effectively limits forefoot motion.

A wide assortment of shoes has been used by the athletes participating on the artificial turf at Rice Stadium. These have included everything from tennis shoes to soccer shoes to specially designed turf shoes. Athletes sustaining injuries to the MP joints all acknowledged wearing lightweight, flexible shoes at the time of their injury. These shoes are considerably more flexible in the forefoot than the traditional cleated shoe (Fig. 11). No player has had an MP joint injury resulting in loss of playing time in the newly designed turf shoe with a stiffened forefoot or while using a spring steel plate incorporated into an orthotic device placed within the shoe (Fig. 12). Unfortunately, this makes the shoe heavier, and it is difficult to get athletes to comply with their usage until they have sustained an injury.

It has been the authors' impression that the more severe MP joint injuries have occurred in football players with a preexisting limitation to first MP motion. This is in contradistinction to the findings of Coker et al.[3] We would readily admit to the difficulty of establishing with certainty whether loss of motion predisposes to injury or injury results in loss of motion. Nevertheless, we began measuring the first MP joint motion of all football players at Rice University at the beginning of the 1985 football season. These measurements revealed 10 athletes who had reduced motion (less than 60 degrees dorsiflexion) in their first MP joints from a group of 90 football players who were measured. Those 10 athletes, including three players who had been injured during the prior year, were all treated in a preventive fashion during the 1985 football season. This involved wearing a turf shoe with a stiffened forefoot

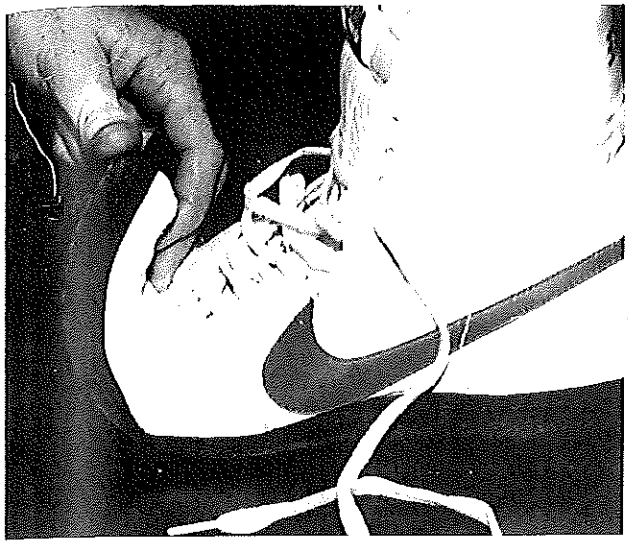

Fig. 11. Example of highly flexible, lightweight shoe used on artificial turf.

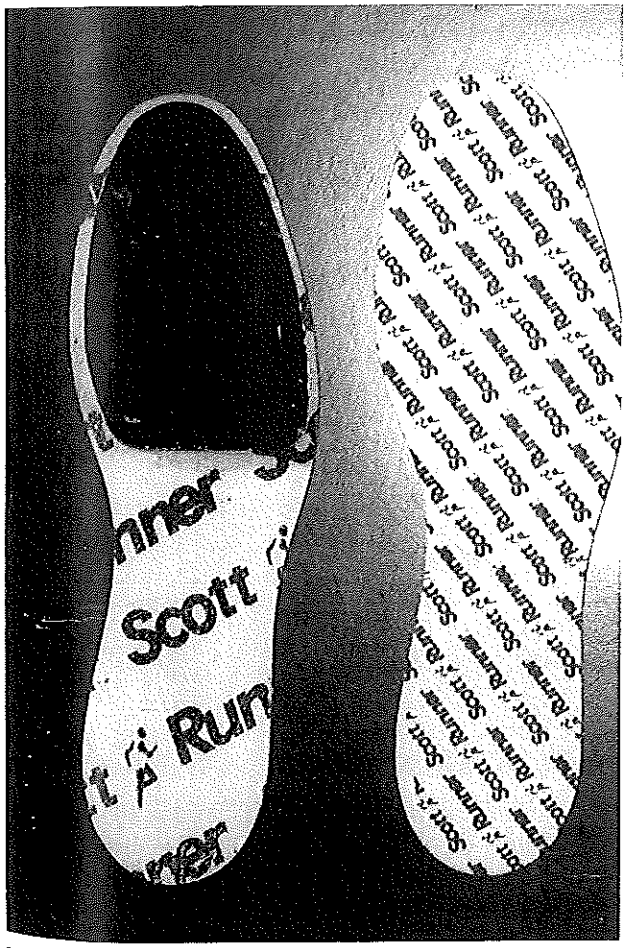

Fig. 12. Example of commercially available orthotic device with steel spring plate in forefoot.

or the use of an orthotic device which incorporates a spring steel plate into the forefoot. Although four turf toe injuries occurred during the 1985 season, all were minor and no loss of playing time resulted. Only two of these injuries occurred in players who were receiving prophylactic treatment. Both of these were grade 1 capsular sprains. Empirically, one would expect that a reduction in severity of injury related to preventive treatment would also reduce the possibility of late sequelae.

Although Coker et al.[3] mentioned several players with long-term consequences from their MP joint injuries, little has been written about this. Recent publicity given to professional football players with sequelae from MP joint injuries[17] encouraged us to search out former athletes who had this problem. Although follow-up has been difficult and remains incomplete, several interesting findings have been uncovered in our preliminary contacts. Two patients have shown progressive hallux valgus deformity during the 10 years since their injuries (Fig. 13, A and B). The relationship to their turf toe injury is unclear since many factors play a role in the development of hallux valgus. Nevertheless, we found this to be an interesting observation at follow-up. Several cases of early hallux rigidus and arthritic change have also been noted (Fig. 14, A–D). These radiographic changes have correlated with continuing symptoms and are found almost exclusively in players with more severe sprains. We think this is a result of damage to articular cartilage and subchondral bone during compression at the time of the original injury. Long-term clinical and radiographic follow-up of this series of athletes is being continued.

SUMMARY

Injury to the MP joints in athletes is an increasing problem primarily attributable to the use of overly flexible shoes on an unforgiving playing surface. More supportive shoewear should reduce the incidence and severity of this injury. Individual anatomical factors may play a role, and players with less than 60 degrees of dorsiflexion in the first MP joint should be protected. Long-term consequences of MP joint sprains can occur and warrant appropriate treatment of the athlete at the time of injury. This should include ice, compression, protective bandaging, medication, and rest. Gradual return to sports activity in a shoe with forefoot support can occur once the player's symptoms allow. Injections in these injuries are contraindicated since this can mask significant pathology and may result in a more severe injury. Ongoing follow-up will be necessary to determine whether significant joint changes requiring surgical intervention will develop in these athletes.

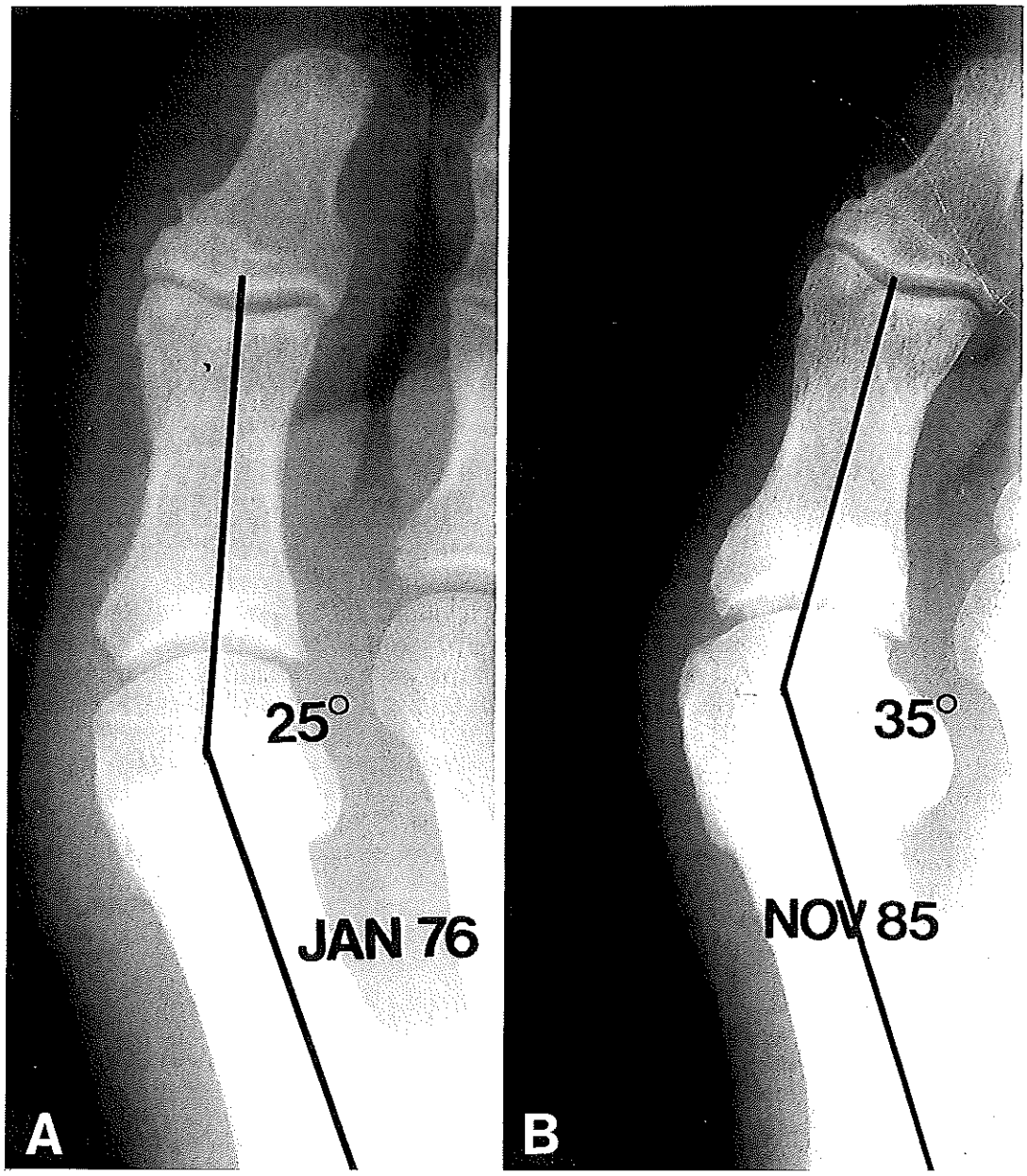

Fig. 13. Hallux valgus developing after grade 3 turf toe injury. *A*, AP radiograph taken 5 months postinjury demonstrating 25 degree HV angle. *B*, AP radiograph taken almost 10 years later showing increase in HV angle to 35 degrees and early degenerative changes.

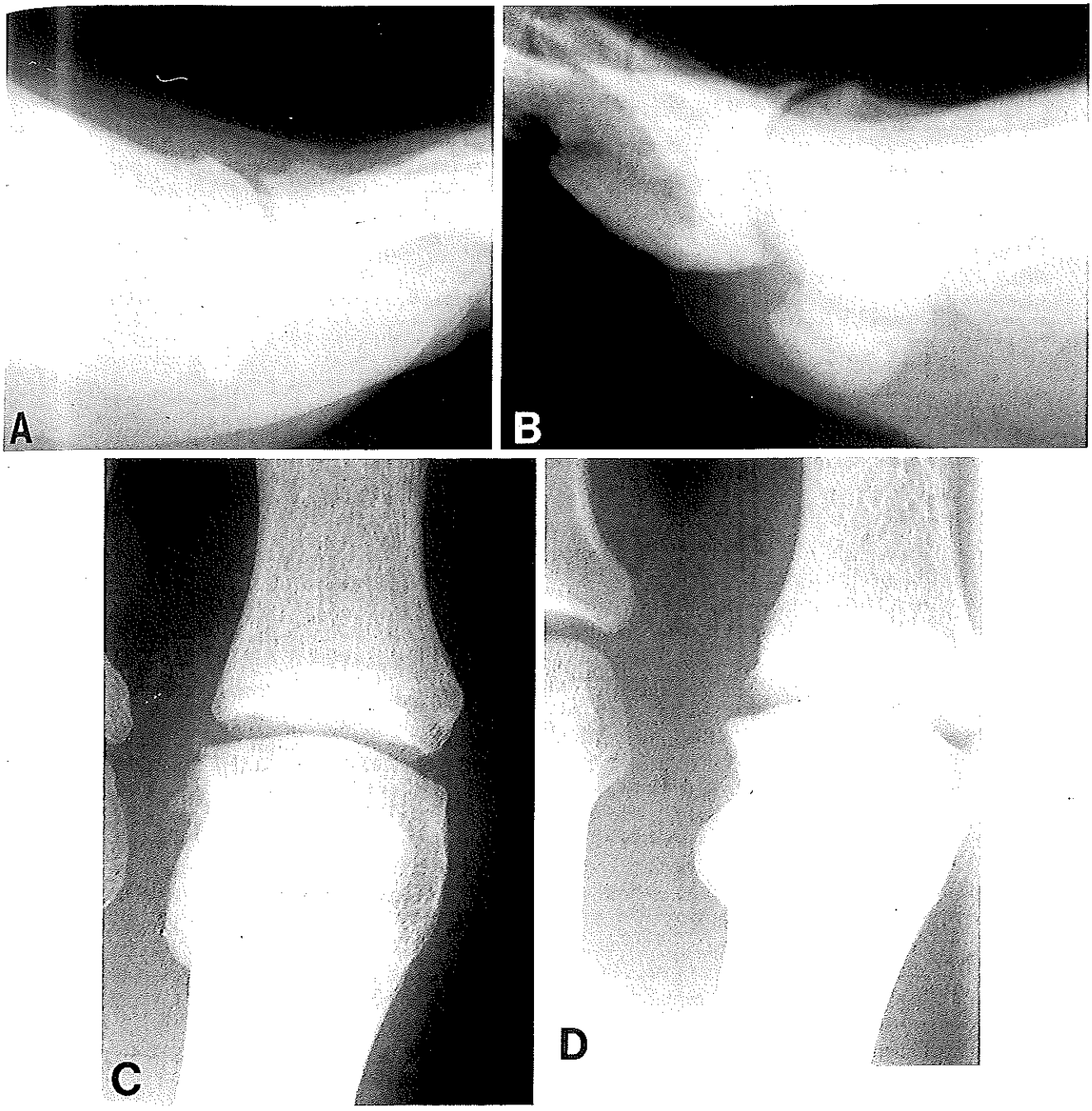

Fig. 14. *A–D.* Examples of degenerative changes of hallux rigidus in players with prior turf toe injuries.

CONCLUSION

Injury to the MP joints in athletes is possibly preventable and certainly treatable. The time loss associated with the acute injury and the possibility of symptomatic residuals warrants our continued efforts in these areas.

ACKNOWLEDGMENTS

The authors thank Dr. David Hildreth for allowing them to use the case of one patient from his practice.

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