Journal of Orthopaedic Surgery 2004;12(2):210–215

Profile of bilateral anterior cruciate ligament injuries: A retrospective follow-up study

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ABSTRACT

Purpose. To assess the mechanism of injury of anterior cruciate ligaments, surgical results, and radiographic findings among patients with bilateral knee injuries, and to compare these features with those of patients sustaining unilateral injuries.

Methods. From 1977 to 1988, among 458 patients with injury of anterior cruciate ligament operated in our hospital, 11 were of bilateral injury, in whom 10 could be followed up. A laxity score was calculated to evaluate laxity of 7 joints. A notch width index was measured to show the narrowing of femoral notch.

Results. The mean follow-up duration was 3 years 3 months. All 10 patients with bilateral injury of anterior cruciate ligaments were female, and 90% had non-contact injuries. The mean (standard deviation) laxity score was significantly higher in the bilateral injury group than in the unilateral injury group (3.3 [1.4] versus 2.2 [1.4] points; $p<0.05$). The mean notch width index was significantly lower in the bilateral injury group than in the healthy group (0.278 [0.025] versus 0.294 [0.031]; $p<0.05$). The mean age at the time of the first injuries was significantly lower among the bilateral injury group than among the unilateral injury group (16.6 [2.1] years versus 19.8 [6.1]; $p<0.05$). The level of return to full sporting activities was low in the bilateral group.

Conclusion. These results suggest that several factors are involved in the occurrence of the anterior cruciate injuries. Besides being younger at the time of the first injury, patients in bilateral injury group had higher mean laxity score and lower mean notch width index than unilateral injury group. Most of the injuries in bilateral group were of non-contact type.

Key words: *anterior cruciate ligament; joint instability; knee injuries*

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INTRODUCTION

Injuries of the anterior cruciate ligaments (ACL) can occur during participation in sports, and are classified into two types, depending on the mechanism of injury: contact and non-contact. Non-contact injury is more common. Souryal et al.[1] reported that 58 (79.5%) of 73 ACL injuries were non-contact. The aetiology of ACL injuries, however, is probably multifactorial. By examining patients with injuries of the ACL who underwent surgery at our hospital, we compared the age, activity level, injury mechanisms, surgical results, and radiographic findings between those who had bilateral injuries and those who had unilateral injuries.

MATERIALS AND METHODS

Surgical treatment of injuries of the ACL in 458 knees was performed at Kowan Hospital in Japan between January 1977 and December 1987. A total of 161 patients—54 males and 107 females—had unilateral injuries and could be followed up after surgery. The mean age of 161 patients at the time of injury was 19.8 years (range, 12.0–45.0 years). Injuries were bilateral in 11 patients (i.e. 22; 4.8% of knees), one of whom was lost to follow-up. The mean age of the other 10 patients—all females—at the time of surgery was 18.2 years (range, 12.8–23.7 years). The patients were operated on on separate occasions. The mean follow-up duration was 3.3 years (range, 1.1–7.4 years). Because the period of treatment spanned more than 10 years, different surgical methods were used: for example, primary suture of the ACL and reconstruction using the iliotibial band in 7 knees, reconstruction using semi-tendinous muscles and the iliotibial band in 6 knees, and reconstruction using semi-tendinous muscles and the gracilis muscle ligament in 2 knees.[2,3] Some injuries were complicated, and involved the medial meniscus alone in 5 knees, the medial meniscus and posterior cruciate ligament in one knee, the lateral meniscus and lateral collateral ligament in one knee, and the medial and lateral menisci in one knee.

The author examined all patients and investigated the types of injuries and level of sports that caused them. Patients were also classified according to how they returned to sporting activities: group A, patients returning to the former level of sporting activities; group B, those returning to sporting activities with a reduced ability; group C, those turning to other sports; and group D, those who discontinued sports.[2]

Joint mobility and other factors were also evaluated. According to the Nakajima, Lachman, and anterior drawer tests, instability was described as severe or definite, slight, and no instability. The Nakajima test is a reverse pivot shift test. The flexibility of 7 joints (wrist, knee, spine, elbow, shoulder, ankle, and hip) was assessed with the joint laxity test (Fig. 1).[4] Each flexible joint was given one point; a total of 7 points was the full joint laxity score, signifying maximum flexibility.

The standing femorotibial angle—the lateral angle between axes of femoral and tibial shafts—was measured by using anteroposterior radiographs of the knee in the standing position. The inclination angle of the tibial plateau—the average inclination of medial and lateral tibial plateau to the tibial shaft—was measured by using lateral radiographs. A line was drawn from the popliteal groove parallel to the joint surface on the images of the intercondylar fossa, and the notch width index—the ratio of the width of the intercondylar notch to that of the distal femur—was measured (Fig. 2). This method was based on the one described by Souryal et al.[1] However, we considered that their method would give the anterior outlet—the anterior portion and the narrowest site—of the intercondylar fossa, we measured the clear osteosclerotic posterior arch and regarded it as the width of the intercondylar fossa.

The laxity score and femorotibial angle in the standing position in the bilateral injury group were compared with those in the unilateral injury group. Comparisons of the inclination angle of the tibia and notch width index were made among the bilateral injury, unilateral injury, and the healthy group of 21 females (23 knees) with no ACL injury. Student's *t* test was used for statistical comparisons.

RESULTS

All bilateral ACL injuries were sustained during sporting activities: basketball in 8 knees, gymnastics in 6 knees, volleyball in 3 knees, handball in 2 knees, and javelin-throwing in one knee. All injuries were spaced apart in time. The first injuries were of the non-contact type in 8 knees and of the contact type in 2 knees, whereas the second injuries in the other knees were of the non-contact type. Of the 20 injured knees, 18 (90%) were of the non-contact type, the most common cause of which was landing from a jump (10 knees), followed by sudden stopping during basketball games (3 knees), dashing, cross-stepping, stepping, treading, and falling from a horizontal bar (one knee each). One of the 2 contact-type knee

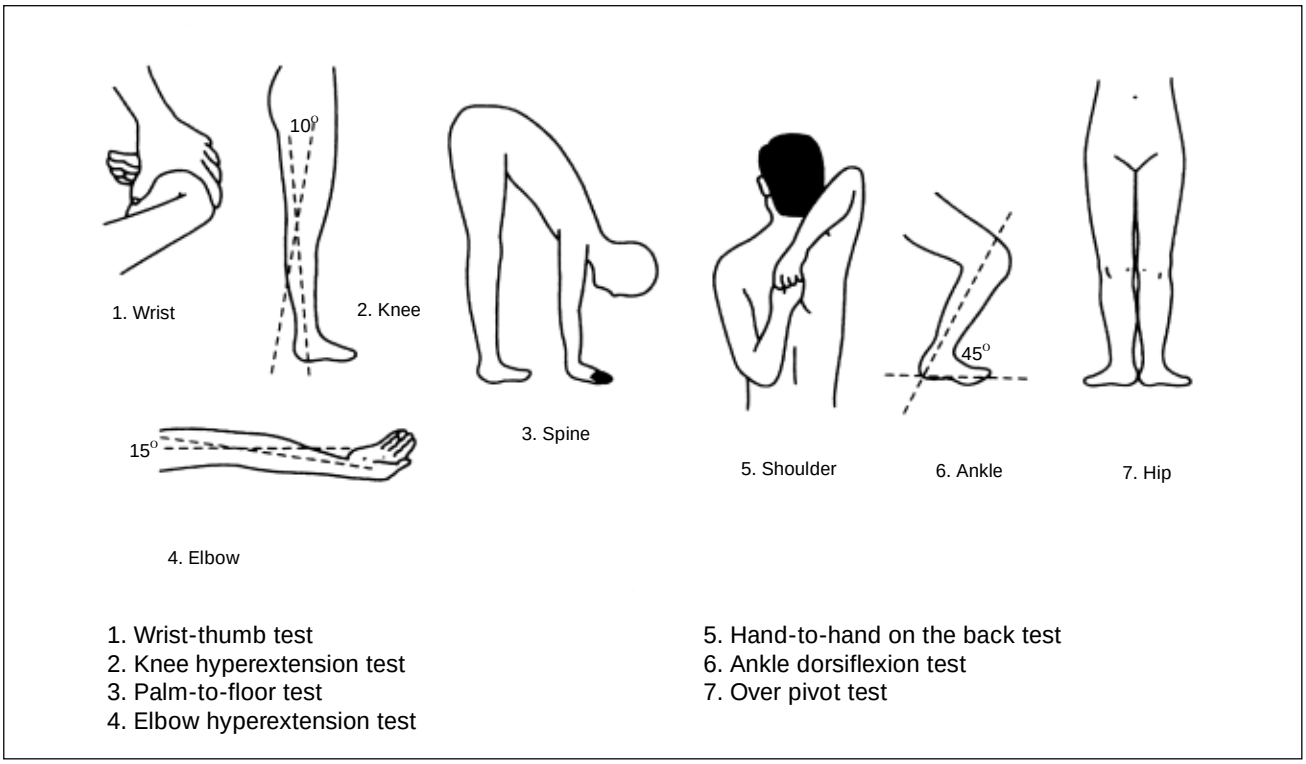

Figure 1 Joint laxity test: the laxity of 7 joints is examined; 7 points is the maximum score.

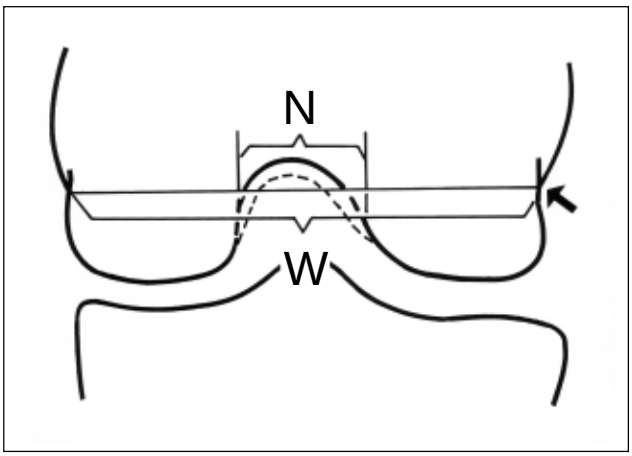

Figure 2 Calculation of the notch width index: a line is drawn from the popliteal groove parallel to the joint surface on the X-ray image of the intercondylar fossa; the notch width index is the width of the osteosclerotic posterior arch of the intercondylar notch (N) divided by the width of the distal femur (W).

injuries was due to a crash with other players during jumping, and the other was caused by the lateral knee being treaded on by a player during shooting.

The mean age at the time of the first injuries was 16.2 years (range, 12.7–19.3 years), and that at the time of the second injuries was 18.6 years (range, 13.5–23.5 years). The mean interval between the first and the second injuries was 2.4 years (range, 0.3–6.2 years). After the first injuries, 6 patients underwent surgery as the primary treatment, whereas 4 did not. In the 6 treated patients, the mean interval between the first and second injuries was 3.3 years (range, 1.4–6.2 years); in the 4 untreated patients, it was 1.2 years (range, 0.3–2.9 years) [Fig. 3].

After surgical treatment of the first injuries, and on the basis of how sports were resumed, 3 patients were classified as group A, 6 as group B, and one as group C. After surgical treatment of the second injuries, one patient was classified as group A, 7 as group B, one as group C, and one as group D.

The postoperative results of the Nakajima test showed no instability in 16 (80%) knees, slight instability in 3 (15%) knees, and definite instability in one (5%) knee. The results of the Lachman test showed no instability in 11 (55%) knees, slight instability in 4 (20%) knees, and definite instability in 5 (25%) knees. The results of anterior drawer tests showed no instability in 10 (50%) knees, slight

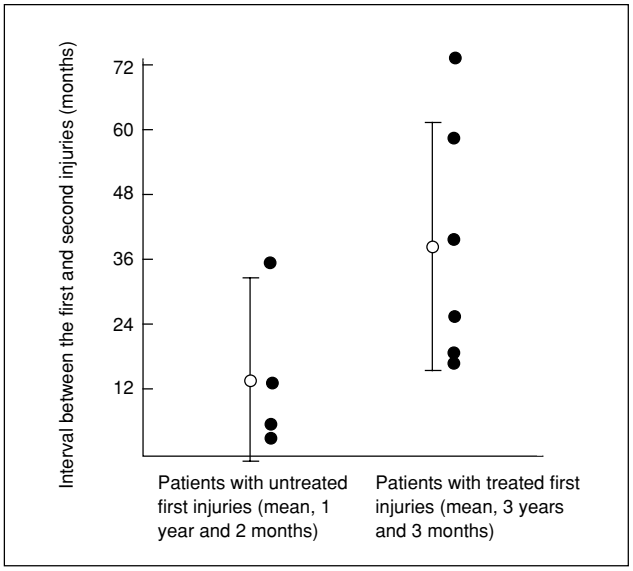

Figure 3 The interval between the first and second injuries of the knee was shorter in patients with untreated first injuries than in the patients with treated first injuries.

instability in 6 (30%) knees, and definite instability in 4 (20%) knees. Upright sitting was possible for 8 patients and impossible for 2. Complete extension of the knee was possible for all patients, but hyperextension was observed in 4 patients. Fixed flexion deformity was absent from all patients. No patient had symptoms in the meniscus, such as McMurray's symptom. Prepatellar sensory disorder was observed in 5 knees, and muscular hernia after collecting the iliotibial band in 4 knees.

The mean laxity score was 3.3 points (range, 2–6 points; standard deviation [SD], 1.4 points) for the 10 females in the bilateral injury group, whereas it was 2.2 points (range, 0–6 points; SD, 1.4 points) among 38 females in the unilateral injury group who could be examined for joint laxity test. The laxity score was significantly higher in the bilateral injury group than in the unilateral injury group ($p<0.05$), indicating that the flexibility of the knees was higher in the bilateral injury group than in the unilateral injury group.

The mean femorotibial angle in the standing position was 176.6° (SD, 3.6°) in the first injured knees and 176.5° (SD, 2.6°) in the second ones, indicating that there was no difference between the first and the second injured knees. The mean femorotibial angle in the standing position was 176.5° (SD, 3.1°) in the knees of bilateral injury group, which did not differ from that in the unilateral injury group (177.0°; SD, 2.8°). The mean inclination angle of the tibia was 12.8° (SD, 3.1°) in the bilateral injury group, 12.9° (SD, 3.7°) in the unilateral injury group, and 11.9° (SD, 3.2°) in the healthy group. There were no differences among the 3 groups.

The mean notch width index was 0.278 (SD, 0.025) in the bilateral injury group, 0.294 (SD, 0.031) in the unilateral injury group, and 0.304 (SD, 0.025) in the healthy group. It was significantly lower in the bilateral injury group than in the healthy group ($p<0.05$), and slightly lower in the bilateral injury group than in the unilateral injury group.

The 10 patients in the bilateral injury group were also compared with all 161 patients with unilateral ACL injuries in whom follow-up observation was possible. The mean age at the time of the first injuries was 16.6 (SD, 2.1) years in the bilateral injury group which was significantly lower than that in the unilateral injury group of 19.8 (SD, 6.1) years ($p<0.05$; 21.9 [SD, 5.9] years for males and 18.8 [SD, 6.0] years for females). The sporting activities that caused the first injuries in the bilateral injury group were at the national level (10%), university level (10%), high school level (70%), and junior high school level (10%); no injuries were due to leisure activities only. With regard to the level of return to full sporting activities, the rates of groups A, B, C, and D were 10%, 70%, 10%, and 10%, respectively, in the bilateral injury group; and 35%, 40%, 19%, and 6%, respectively, in the 107 female unilateral injury group. The rate of group A was lower in the bilateral injury group than in the unilateral injury group, indicating that the level of return to full sporting activities was lower in the bilateral injury group.

DISCUSSION

Souryal et al.[1] reported a study in the United States that bilateral ACL injuries occurred in 45 of 1120 patients (90 knees; 7.7% of a total of 1165 knees) with ACL injuries. The incidence of bilateral ACL injuries was lower in our study, at 4.8%, probably because of the characteristics of sport activities in Japan and differences between the sexes: in the study by Souryal et al.,[1] 41 patients with bilateral ACL injuries in whom follow-up observation was possible consisted of 28 males and 13 females, and the causal sporting activities of the first injuries were football (25.6%), basketball (20.7%), and soccer (11.0%). In our study, all patients were female, and the most common causal sporting activities were basketball and gymnastics.

Of the 73 ACL injuries of the knee studied by Souryal et al.[1] for which the injury mechanism was known, 58 (79.5%) were caused by a cutting motion. In our study, non-contact type injuries accounted for 90% of cases, and half of the knees (10 knees) were

injured during landing from a jump. There were no patients with injuries caused by a cutting motion.

Souryal et al.[1] reported that the mean age of patients with bilateral ACL injuries at the time of their first injuries was 19.8 years and that the mean interval to the injuries in the second knee was 3.9 years. In comparison, because most patients in our series were female junior and senior high school students, they were, on average, much younger at the time of their first injuries (16.2 years); the mean interval to the second injuries in the other knees was also shorter—2.4 years overall and 3.3 years for those whose first injuries were treated. In the patients with untreated first injuries, the mean interval between the first and second injuries was particularly short, at 1.2 years. Hence, patients with ACL injuries who are younger than 16 years should be careful about the occurrence of injuries in the other knee. Female junior and senior high school students with unilateral ACL injuries may have a higher risk of sustaining injuries in the other knee when landing or jumping, when returning to club activities and physical education, irrespective of whether the first injuries are surgically treated.

Nicholas[5] examined the relationship between joint flexibility and the incidence of injuries. We previously reported that the flexibility of joints was closely correlated with the occurrence of bilateral ACL injuries.[2] In our study, the laxity score was significantly higher in the bilateral injury group than in the unilateral injury group. We considered that this difference reflected not only the relaxation of joints but also the relaxation of connective tissue in the entire body, including the ACLs. This relaxation was considered to be a factor of ACL injuries.[6]

Palmer[7] reported in 1938 that the ACL is extended in the externally rotated position by the bending of the knee, and is injured by impingement with the intercondylar fossa. Norwood and Cross[8] also reported that the extended ACL becomes impinged in the anterior part of the intercondylar fossa. Houseworth et al.[9] suggested that ACL injuries are caused by the narrowing of the posterior arch of the intercondylar fossa. Furthermore, Anderson et al.[10] reported that stenosis of the anterior opening of the intercondylar fossa, which was observed by computed tomography (CT), is related to ACL injuries. Using CT, Harner et al.[11] had found significant evidence of intercondylar notch stenosis secondary to increased lateral condylar width among bilateral ACL-injured patients compared with non-injured individuals.

Schickendantz and Weiker[12] measured the intercondylar notch by including the notch width at the most narrow distal opening of the notch and the condylar width at its greatest width above the joint line. In contrast, we measured the notch width index according to the method of Souryal et al.[1] which gives measurements of the narrowest anterior outlet of the intercondylar fossa. The advantages of this method are as follows:

(1) Imaging of the intercondylar fossa is easier than conducting CT and magnetic resonance imaging;
(2) The popliteal groove can be used as a marker for measuring the width of the intercondylar fossa;
(3) Being a ratio, the notch width index is not affected by the shape of the intercondylar fossa itself; and
(4) The width of the intercondylar fossa can be easily measured, and accurate comparisons are possible.

As in the study of Houseworth et al.,[9] we considered that ACL injuries are caused by the posterior arch of the intercondylar fossa, and measured the width of the clear osteosclerotic posterior arch on X-ray images of the intercondylar fossa. It was shown that a small notch width index—the narrowing of the posterior arch—was closely related to the occurrence of ACL injuries.

Huston et al.[6] reported ACL injuries among female athletes in 2000. A female athlete with an anterior cruciate injury may be an individual whose Q-angle is significantly larger than average, has a notch width significantly smaller than most, has joints classified as 'ligamentous lax', and is weaker than her male counterparts. A large proportion of ACL injuries occur when an athlete lands from a jump. Landing imposes forces on the body that must be absorbed primarily by the lower extremity. If loads become too great for the body to accommodate, or if impact absorption fails, an injury will occur. Our results suggest that several factors are involved in the occurrence of ACL injuries. Further investigation is necessary to elucidate the mechanism of injury and thus formulate prevention strategies for people who play sports.

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