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Radiographic and intraoperative intercondylar notch width measurements in men and women with unilateral and bilateral anterior cruciate ligament tears

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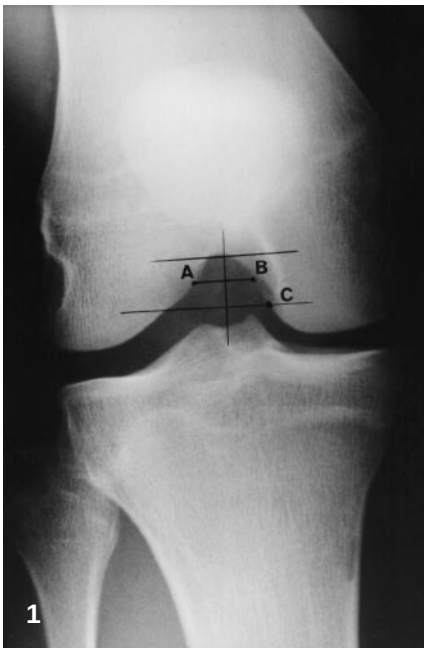
Abstract The purpose of this study was to compare the measurements of the intercondylar notch width (NW) in men and women radiographically and intraoperatively, and to determine if the radiograph would demonstrate a difference in the patients with unilateral and bilateral anterior cruciate ligament (ACL) tears compared with non-injured patients. The control groups consisted of 100 men and 100 women from our young adult clinic population without a history of knee injury or clinical evidence of ligamentous deficiency. The study group consisted of 90 men with bilateral and 297 with unilateral ACL reconstructions (mean age 25.1 years, range 13–53 years) and 41 women with bilateral and 129 with unilateral ACL reconstructions (mean age 22.3 years, range 13–48 years). On 45° flexion weight-bearing radiographs, we measured the intercondylar NW in controls and patients at one-half notch height from the lateral edge of the articular margin of the medial femoral condyle to the apex of the intercondylar notch. Intraoperatively, the surgeon took a direct measurement at the same site with sterile calipers. The surgeon was unaware of the radiographic measurement. The mean radiographic NW measurements for women were 12.8 mm in the bilateral group, 13.8 mm in the unilateral group, and 14.5 mm in the control group ($P < 0.05$) and, for men, 15.3 mm in the bilateral group, 15.8 mm in the unilateral group, and 16.9 mm in the control group ($P < 0.05$). The preoperative radiographic NW measurements correlated with actual intraoperative measurements ($r = 0.72$, $P < 0.01$). We conclude that the intercondylar NW of the femur is narrower in women than men, and, in both men and women, the NW is narrower in patients who sustain ACL tears compared with controls.

Key words Intercondylar notch width · Anterior cruciate ligament tears · Radiographic and intraoperative measurements

Introduction

Causes and predisposing factors for anterior cruciate ligament (ACL) tears with the intent of identifying an at risk population and preventing injury have challenged investigators. Several proposed risk factors for sustaining a tear of the ACL are mentioned in the literature [2, 3, 11, 13]. These factors include the sport played at the time of injury, shoe-surface interface, field conditions, body movement, strength, endurance/conditioning, reaction time, muscle imbalance, skill level, joint laxity, limb alignment, fatigue, age, gender, ligament size, and intercondylar notch size. The sheer number of supposed risk factors for an ACL tear and the lack of clear scientific proof of their causality make it difficult to lend credibility to one factor over another.

Several investigators [1, 4, 7, 9, 10, 17, 18] suggested that femoral intercondylar notch stenosis is a high risk factor for ACL injuries. The relative width of the intercondylar notch of the femur measured radiographically



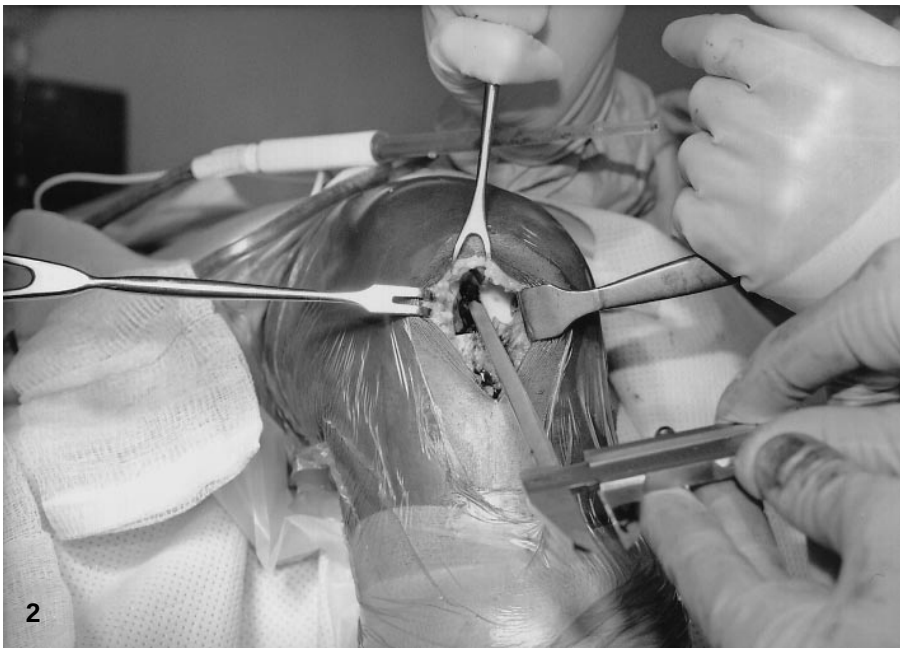


Fig. 1 The radiograph shows the method we used for measuring intercondylar notch width. A line is drawn across point *C* which corresponds to the lateral edge of the articular margin of the medial femoral condyle. Another line is drawn at the level of the apex of the intercondylar notch. The width of the intercondylar notch (distance from point *A* to point *B*) is measured at one-half notch height

Fig. 2 The intraoperative notch width was measured with sterile calipers

has been expressed as a ratio of notch width (NW) to femoral condyle width, i.e., the "notch width index" (NWI). While some investigators [1, 7, 9, 10, 17, 18] concluded that the radiographic NWI of patients with unilateral and bilateral ACL tears is significantly smaller than the NWI of patients without an ACL tear, others [5, 6, 15] determined that there is no difference between these groups. Different radiographic and measurement techniques were used in these studies [5, 6, 15]. None of the investigators indicated efforts to correlate actual intraoperative notch dimensions and radiographic measurements in patients with ACL tears. Souryal and Freeman [17] are the only authors who demonstrated a difference in femoral intercondylar NWI between men and women.

The NWI is a ratio of two independent variables; it is not a direct measure of the absolute width of the intercondylar notch of the femur. A standing posteroanterior radiograph of both knees at 45° of flexion [14] provides an excellent view of the dimensions of the intercondylar notch of the femur. With a small plastic metric ruler, the NW can be measured directly on the radiograph. The measurements are absolute values. Radiographs of the knee are non-invasive procedures.

The purpose of this study was to measure the radiographic intercondylar NW on the Rosenberg view in a population without ACL tears (normal knees), and to determine if there was a difference between the NW of men and women in the control groups and a population of patients with unilateral and bilateral ACL tears. Also, we sought to determine if there was a correlation between intraoperative measurements and those measurements taken directly from the radiographs.

Patients and methods

One hundred men and one hundred women without a history of knee injury and no evidence of an ACL tear or other ligament injury on physical examination served as the control groups. The study population consisted of 90 men with bilateral and 197 with unilateral ACL reconstructions (mean age 25.1 years, range 13–53 years) and 41 women with bilateral and 129 with unilateral ACL reconstructions [16] (mean age 22.3 years, range 13–48 years).

Preoperative weight-bearing posteroanterior knee radiographs were obtained according to the Rosenberg technique [14] and a guide was used to maintain 45° of knee flexion. The X-ray beam was angled downward 10° with a tube to film distance of 101.6 cm and the patient's patella touched the film cassette.

The NWs were measured on the radiographs at one-half notch height from the lateral edge of the articular margin of the medial femoral condyle to the apex of the intercondylar notch (Fig. 1). With a metric ruler, an independent observer measured the NWs before ACL reconstruction was performed. To test reliability, a random sample of 30 radiographs were measured twice by four observers. Interobserver reliability for measuring NW was 97% and the intraobserver reliability was 81%. The surgeon was blinded to these measurements.

Intraoperative measurements were obtained at the time of ACL reconstruction. The patients were positioned supine and a bolster was placed behind the upper thigh to place the patient in approximately 45° of hip flexion. The direct measurement of the NW was made with a sterile modified Vernier caliper (Fowler Tools and Instruments, Chicago, Ill., USA) at one-half notch height through a

small medial arthrotomy (Fig. 2). The miniarthrotomy is part of the standard technique for ACL reconstruction in this patient population.

Statistical analysis was performed using Duncan's multiple range test and statistical significance was accepted at $P \leq 0.05$. A Pearson linear correlation coefficient was generated between preoperative radiographic NW measurements and actual intraoperative NW measurements.

Results

The distribution of women and men with NWs as measured radiographically is given in Table 1. The means of the radiographic NW for each subgroup are given in Table 2. All groups of women (control, unilateral, and bilateral) had significantly smaller NWs than all of the groups of men ($P < 0.01$).

Table 1 Distribution of radiographic notch width (NW)

	NW: male		
	Bilateral (n = 90)	Unilateral (n = 297)	Control (n = 100)
6–11 mm	3	23	3
12–13 mm	28	32	5
14–15 mm	19	71	26
16–17 mm	21	96	22
18–21 mm	17	66	40
22–24 mm	2	9	4
	NW: female		
	Bilateral (n = 41)	Unilateral (n = 129)	Control (n = 100)
8–11 mm	10	16	8
12–13 mm	13	45	31
14–15 mm	17	43	27
16–17 mm	1	21	23
18–21 mm	0	4	11
22–24 mm	0	0	0

Table 2 Means of radiographic NW measurements (*ACL* anterior cruciate ligament)

	Men[a], mean NW ± SD (mm)	Women[b], mean NW ± SD (mm)	P value
Controls	16.9 ± 2.7	14.5 ± 2.4	0.01
Unilateral ACL reconstructions	15.8 ± 2.9	13.8 ± 2.2	0.01
Bilateral ACL reconstructions	15.3 ± 2.9	12.8 ± 1.8	0.01

[a] Within groups of men, there was a statistically significant difference between the controls and the unilateral group ($P < 0.01$) and between the controls and the bilateral group ($P < 0.01$)

[b] Within groups of women, there was a statistically significant difference between the controls and the bilateral group ($P < 0.01$) and between the unilateral and bilateral groups ($P < 0.01$)

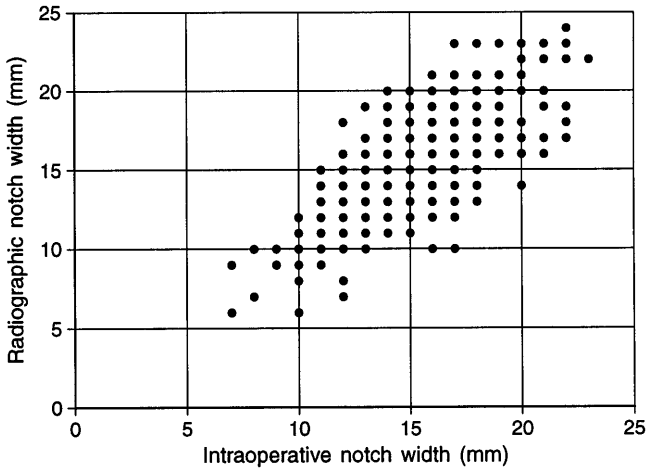


Fig. 3 Preoperative radiographic intercondylar notch width measurements correlated with actual intraoperative measurements taken at the time of anterior cruciate ligament reconstruction

The preoperative radiographic NW measurements in patients with ACL tears correlated with the actual intraoperative measurements of NW taken at the time of ACL reconstruction ($r = 0.72$, $P < 0.01$) (Fig. 3).

Discussion

The results of this study showed that both men and women with unilateral and bilateral ACL tears had significantly narrower femoral intercondylar notches than control patients. Also, women in all comparable groups had narrower NWs than men. According to a recent report [2], women tear their ACL at a higher rate than men. Therefore, it appears that the NW may be an prognostic indicator for disruption of the ACL. This supports the findings of a previous study by Good et al. [4] who found significant differences in actual NW measurements between patients with ACL tears and controls (cadaver knees).

Previous reports [1, 5–7, 15, 17] which examined the relationship of notch dimensions to ACL tears have used various plain radiographs, computerized axial tomography, and magnetic resonance imaging. Herzog et al. [6], in a study of ten cadaveric knees, measured the intercondylar NW with anteroposterior notch views and the values were compared with direct measurements. They found plain film measurements to be significantly different from the cadaveric measurements.

The standing bilateral posteroanterior 45° flexion radiograph [14], which was used in this study, is part of a standard set of knee films obtained in our clinic for ACL as well as other knee injuries. A correlation between the posteroanterior weight-bearing view measurements and the intraoperative measurements was found in our study. We believe the difference in our findings from those of Herzog et al. [6] may be because, with the posteroanterior

weight-bearing view, the patella rests against the film cassette and there is very little magnification of the notch.

Our purpose for determining if a correlation between the radiographic and intraoperative measurements existed was solely to compare the NW of patients without ACL tears (of whom we could not obtain direct measurements) with patients who had ACL tears. We used the same equipment, the same X-ray technician, and the same technique to obtain the radiographs. Our methods allowed us to collect enough data to make comparisons between men and women and between patients with unilateral and bilateral ACL tears.

There were absolute differences in intercondylar NWs between men and women. In all groups, women had significantly smaller notches. This difference was emphasized by the fact that the largest group of women (normal knees) had significantly smaller notches than the smallest group of men (knees with bilateral ACL tears).

The distribution of NWs in the bilateral, unilateral, and control groups for men and women is given in Table 1. Fifty women (97%) in the bilateral group, 81% of the unilateral group, and only 66% of the control group had NWs ≤ 15 mm. There were more patients in the unilateral and bilateral groups that had small notches than patients in the control group. Forty men (80%) with bilateral ACL tears and 75% of men with unilateral ACL tears had NWs ≤ 17 mm. Fifty-six (56%) of the control group had NW measurements ≤ 17 mm. Similar to the groups of women, there were increasingly more men in the unilateral and bilateral groups with NWs ≤ 17 mm compared with the control group. Our analysis (Table 2) shows an association between narrow intercondylar notches and the presence of an ACL tear. Women have a higher rate of ACL injury than men [2]. The absolute NW (which is smaller in women) may play a role in this propensity for injury.

In a study of Norwegian women handball players, radiographic NW was measured in 20 athletes with a previous ACL tear and 26 athletes without ACL injury [10]. Because right and left knee measurements of each subject correlated (r = 0.84), the authors used the NW measurement of the uninjured knee for athletes that had prior ACL reconstructions. They found that the anterior opening of the intercondylar notch was significantly narrower in the healthy knee of the injured group compared with controls. Lund-Hanssen et al. [10] reported that athletes with a radiographic NW ≤ 17 mm were six times more likely to tear the ACL than athletes with a NW > 17 mm.

According to recent National Collegiate Athletic Association injury data, over a 5-year period women soccer players had an ACL injury rate 2.4 times higher than their male counterparts, and women basketball players had an ACL injury rate 4.1 times higher than men [2].

The problem of a small notch has been described as a problem of impingement of the notch on the ACL in hyperextension [12], or of the lateral femoral condyle on the ACL causing it to rupture during twisting or cutting maneuvers [3, 5, 8, 9]. This would imply a pathological relationship between the ACL and its surrounding bony vault. Some authors [9, 17, 18] proposed the use of conditioning and/or bracing to prevent ACL rupture from the bony impingement of a small notch. Souryal and Freeman [17] recommended prophylactic notchplasty in patients with stenotic notches at the time of a arthroscopy performed for another problem. No published evidence exists to suggest that conditioning, bracing, prophylactic notchplasty, or any other intervention will help prevent ACL tears in patients with small notches. We suggest that the NW may reflect the size and strength of the ACL. We have not located in our searches any published evidence that indicates that the ACL can increase in size if there is more space available to accommodate it. Because we are proposing that the size of the ACL and not the notch size itself is more important to determining the likelihood of sustaining an ACL tear, we are not recommending a prophylactic notchplasty for preventing ACL tears.

We are concerned that patients with narrower NWs (15 mm was the mean in this study) are at higher risk for sustaining an ACL tear, even though this risk is still small. At this time we are using this information solely to counsel our patients with ACL tears and a narrow NW that they may be at a higher risk for tearing the ACL in the contralateral normal knee. Our data are not conclusive enough to recommend screening or counselling all athletes.

We conclude that the intercondylar NW of the femur is narrower in women than men, and narrower in those who sustain bilateral and unilateral ACL tears versus controls.

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