Brace effects on the unstable knee in 21 cases

A roentgen stereophotogrammetric comparison of three designs

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Three designs of knee braces were investigated in 21 knees with arthroscopically verified old tears of the anterior cruciate ligament. Anterior-posterior and rotatory instability with and without anterior traction were recorded with roentgen stereophotogrammetric analysis. Two of the designs examined reduced the anterior-posterior instability (ECKO, modified Lenox Hill), but not to normal levels. At 20° of flexion, none of the braces decreased the internal rotatory instability, whereas one type (modified Lenox Hill) reduced the external rotatory instability.

There is a considerable uncertainty concerning the effectiveness of knee braces. Epidemiologic investigations have questioned their ability to protect the knee from ligament injuries (Teitz et al. 1987). Performance and muscle strength tests of braced knees have displayed improved (Cook et al. 1989), or impaired performance (Houston and Goermans 1982) or no effect at all (Tegner and Lysholm 1985).

Knee braces have different effects on the stability of the knee depending on loading conditions and orthotic design. Soft tissue and brace interposition are sources of error when assessing instability in the braced knee with arthrometers or goniometers (Forster et al. 1989, Tegner et al. 1988). We have studied the efficiency of three commonly used knee braces as regards their ability to reduce anterior-posterior and rotatory instability after rupture of the anterior cruciate ligament. In this study, we used roentgen stereophotogrammetric analysis (Selvik 1974, 1989) to obtain detailed recordings of skeletal movements during the testing procedure.

Patients and methods

Nineteen patients, 14 men and 5 women, with unilateral tears and one man with bilateral, old tears of the anterior cruciate ligament were studied (Table 1). The mean age was 26 years, and the mean dura-

Table 1. Clinical data of 20 patients

		Associated injuries				Previous surgery				
		None	Rupture			None	Meniscectomy			Anterior cruc. lig.
	n		Medial meniscus	Lateral meniscus	Medial col. lig.		Partial medial	Total medial	Partial lateral	
SKB	7	2	4	1	0	2	3	1	1	2 [a]
ECKO	7	3	4	2	0	4	2	0	1	0
Lenox Hill	7	1	3	3	1	3	3	0	1	0

[a] 1 primary suture of the anterior cruciate ligament, 1 pes anserinus transposition.

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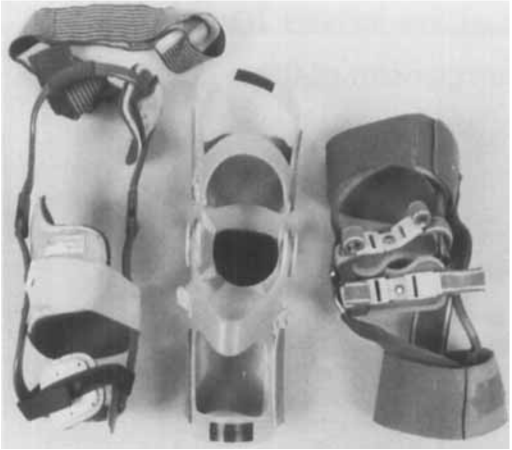

Figure 1. The tested braces: SKB, ECKO, and modified Lenox Hill.

tion between injury and examination was 5 years. Clinical examination revealed a positive Lachman test, and all but 2 had a positive pivot shift. All the patients had had their injuries verified by arthroscopy. Most of the patients had associated injuries; some had been treated operatively.

Two custom-made (SKB, a modified Lenox Hill) and one ready-made brace (ECKO) were investigated (Figure 1). The designs of our three braces represent three subgroups: the SKB, prophylactic; the ECKO, rehabilitative; and the modified Lenox Hill, functional bracing (Drez 1987, Paulos et al. 1987). We have used all three orthoses for functional as well as rehabilitative bracing (Baker et al. 1989, Gerber et al. 1983, Nicholas 1983, Tegner et al. 1985, 1988).

The SKB brace (LIC, Sweden) is built up by metal frames, hinged laterally and medially, and elastic straps proximally. Immobile moulded pads are attached medially at the knee joint, laterally on the thigh, and anteriorly and laterally on the calf. Elastic straps around the waist prevent the brace from slipping down.

The ECKO (Extension Control Knee Orthosis) brace (Orthomedics, USA), available in three different sizes, consists of a thermoplastic hinged frame with two transverse anterior bars over the thigh and calf. The brace is stabilized to the knee with proximal and distal straps and popliteal bands.

The Lenox Hill brace (Lenox Hill Brace Shop Inc., USA; Nicholas 1983) has metal frames hinged medially and laterally, fixed lateral supports proximally and distally, and a mobile medial support. Above and below the patella, there are adjustable pads. Strips and an oblique elastic strap provide further stability. The modified Lenox Hill brace extends more proximally on the thigh, more distally on the calf, and the contact surfaces against the extremity are larger as compared with the original version (Karlsson and Eghamn 1981).

Each type of brace was tested on seven injured knees. All the injured knees were examined with and without a brace. The intact knees were used as controls excluding the bilaterally injured patient. In-

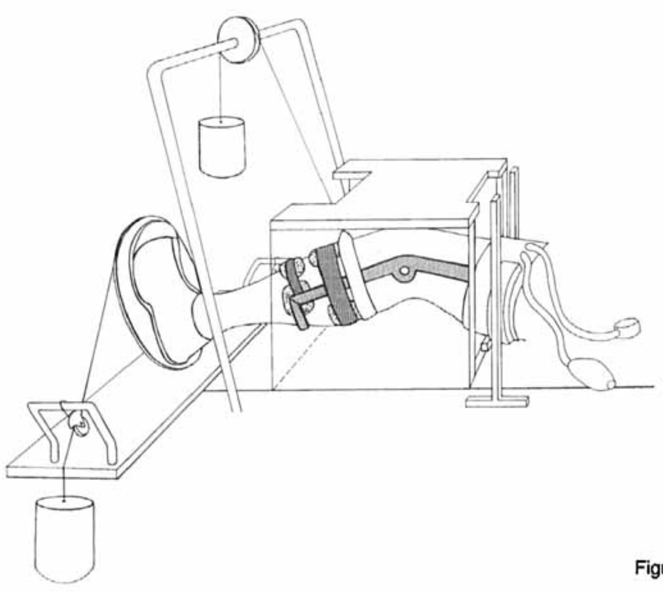

Figure 2. The examination set-up.

formed consent was required to participate in the study.

At the arthroscopy or under local anaesthesia, three to five tantalum balls (0.8-mm diameter) were implanted percutaneously into the distal femur and proximal tibia bilaterally. The tantalum markers were placed as far from each other as possible, creating two polygons (Jonsson et al. 1989).

Roentgen stereophotogrammetric examinations

The patients were examined 6 weeks or later after the insertion of the tantalum balls. The knee was placed in a Plexiglas calibration cage with the patient in the supine position.

The knees were examined in the following test positions (Kärrholm et al. 1988a, 1989; Figure 2):

A. Extended knee.
B. 30° of flexion.
C. 30° of flexion, anterior traction 150 N.
D. 30° of flexion, posterior traction 80 N.
E. 20° of flexion, external rotation 8 Nm.
F. 20° of flexion, internal rotation 8 Nm.
G. 20° of flexion, anterior traction 150 N, external rotation 8 Nm.
H. 20° of flexion, anterior traction 150 N, internal rotation 8 Nm.

On the injured side the extended position was only examined without the brace to calculate the tibial rotations at the subsequent positions (Kärrholm et al. 1989). Thus, the rotations of the injured knee with and without the brace were referred to the same position.

The test series were repeated once with the traction sling surrounding the calf inside the brace (Figure 2). The observed difference between the two applications did not exceed the previously determined reproducibility of the examination (Kärrholm et al. 1988a).

The average translation of the two tips of the tibial intercondylar eminence represented tibial translations. The knees were examined in passive flexion with or without orthosis to evaluate if they displaced the tibia anteriorly-posteriorly or rotated it externally-internally (Kärrholm et al. 1988 b). To investigate the influence of passive knee flexion on the position of the tibial eminence along the sagittal axis, the injured knee of 1 patient was examined at increased passive flexion from 0° to 34°.

The reproducibility (SD) of the anterior-posterior laxity and internal-external rotations has previously been determined to be 0.8 mm (Kärrholm et al. 1988a) and 1.4°, respectively (Kärrholm et al. 1989).

Paired students t-test and Pearson's correlations coefficients were used.

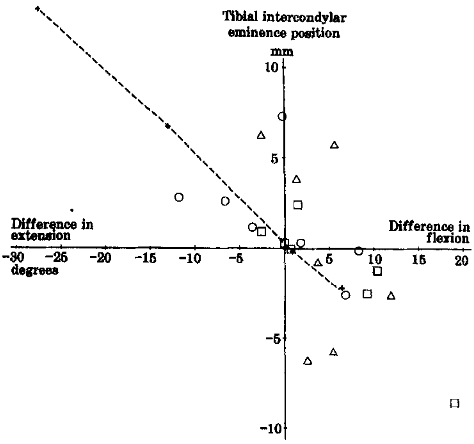

Figure 3. The position of the tibial intercondylar eminence after applying braces. X-axis: change of knee flexion at passive knee flexion between braced and unbraced knees. Y-axis: change of the anterior-posterior position of the tibial intercondylar eminence. The zero point is the tibial position at 30° of flexion without brace. The dotted line shows change of position during proceeding passive flexion in one knee with anterior cruciate ligament rupture.
○ = SKB, □ = ECKO, △ = Lenox Hill.

Results

Knee positioning at 30° of flexion

Anterior-posterior translation (Figure 3). There was an almost linear relationship between the anterior-posterior position of the tibial intercondylar eminence and flexion when performing a passive knee flexion in 1 patient. Thus, the changes in position of the tibial eminence between the unbraced and braced knee were partly due to differencies in flexion between the examinations. The orthosis might also have influenced the translatory tibial positioning. The ECKO brace displayed a correlation ($r = -0.91$, $P < 0.01$) between the difference of flexion (braced-unbraced) and anterior-posterior tibial position, suggesting a small influence of the brace. The SKB and the Lenox Hill braces seemed to have a more unpredictable influence on the relative tibial position (SKB, $r = -0.49$, Lenox Hill, $r = -0.43$, NS).

Table 2. Anterior posterior laxity. SKB group: 7 injured, 7 normal knees. ECKO group: 7 injured, 6 normal knees. Lenox Hill group: 7 injured, 6 normal knees

	AP Laxity		Δ AP Laxity		
	x̄	*SD*		x̄	*P*
All cases					
Normal (N)	5.4	*2.1*	N–I	–8.9	< 0.005
Injured (I)	14.6	*3.9*	I–IB	4.8	< 0.005
Injured-Braced (IB)	9.8	*3.1*	N–IB	–4.2	< 0.005
SKB					
Normal (N)	4.2	*1.4*	N–I	–10.6	< 0.005
Injured (I)	14.8	*4.3*	I–IB	4.7	NS
Injured-Braced (IB)	10.1	*4.6*	N–IB	–5.9	< 0.02
ECKO					
Normal (N)	5.8	*2.6*	N–I	–5.9	< 0.005
Injured (I)	12.3	*3.9*	I–IB	3.8	< 0.01
Injured-Braced (IB)	8.5	*2.3*	N–IB	–2.3	< 0.03
Lenox Hill					
Normal (N)	6.4	*1.6*	N–I	–9.9	< 0.005
Injured (I)	16.7	*2.2*	I–IB	6.0	< 0.005
Injured-Braced (IB)	10.7	*1.8*	N–IB	–4.3	< 0.02

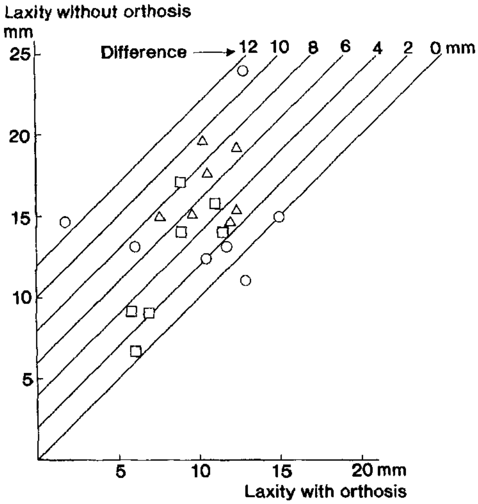

Figure 4. Anterior-posterior instability with (X-axis) and without brace (Y-axis). Diagonal lines represents the difference with and without brace.
○ = SKB, □ = ECKO, △ = Lenox Hill.

Internal-external rotation. Application of the SKB brace resulted in a mean internal tibial rotation of 3.3° ($P < 0.04$). The other two braces did not influence the rotatory position of the tibia.

Anterior-posterior stability tests (Table 2)

The injured knees displayed increased anterior-posterior instability (8.9 (*4.0*) mm, $P < 0.005$) compared with the normal side. The ECKO and the Lenox Hill braces reduced the instability of the injured knees by about one third of the initial values ($P < 0.01$), but not to normal levels (ECKO, $P < 0.03$, Lenox Hill, $P < 0.02$). Two of the seven SKB braces reduced the anterior-posterior laxity to less than half of the initial values, but five of the braces had no or minimum effect. The group tested with the SKB braces did not display reduction of the anterior-posterior instability when the orthosis was applied (Figure 4).

Rotatory instability without traction

The internal and external rotatory instability at 20° of flexion did not differ between normal and injured knees examined without braces. None the less, the Lenox Hill braces decreased the mean external rotatory instability from 13.4° to 8.4° ($P < 0.005$). The SKB and ECKO braces did not have any uniform effects on the external rotatory laxity. None of the three braces affected internal rotatory laxity.

Rotatory instability with anterior traction

When an external rotatory torque was applied to the anteriorly displaced knee, the recorded external rotations decreased on the normal and unbraced injured side ($P < 0.005$) when compared with external rotation without anterior traction. The decrease was greater on the injured side ($P < 0.005$). On the contrary, the internal rotation tended to increase with anterior traction ($P < 0.005$) on both sides and did not differ between the two sides. Simultaneous anterior traction and external rotation resulted in a rotation of 10.3° (*8.1°*) on the intact side and 1.4° (*6.4°*) in the injured knees. ($P < 0.005$). When analyzing all three braces together, they increased external rotation to 4.1° (*6.7°*), but not to normal levels ($P < 0.005$). When analyzing the braces separately, none of the designs influenced the external or internal rotations when examined with anterior traction.

Discussion

Loss of function of the anterior cruciate ligament implies mainly increased anterior-posterior instability (Butler et al. 1980, Cabaud 1983, Kärrholm et al. 1989), but also increased rotatory instability (Girgis et al. 1975, Cabaud 1983, Kärrholm et al. 1989). The increase of the later is small and not a consistent phenomenon. In this study, we could not verify some previously documented rotatory abnormalities. This difference might be due to different techniques of examination or divergent patterns of associated injuries.

Knee flexion changes the rotatory position of the tibia, but is more difficult to estimate owing to individual variability and was therefore not taken into consideration in our study (Kärrholm et al. 1988a).

The ECKO brace seemed to have the smallest influence on tibial position. The other braces examined in almost the same degree of flexion displaced the tibia anteriorly as well as posteriorly. The individual fit of the braces may be of importance.

Colville et al. (1986) stated that the Lenox Hill brace was effective in reducing episodes of giving away by increasing resistance to anterior displacement. They observed that this effect vanished with greater stress forces (about 200 N). Still the Lenox Hill brace has been observed to reduce anterior-posterior instability in anterior cruciate ligament sectioned knees at very high loads (450 N; Wojtys et al. 1987). This observation suggests that the applied loads in our investigation provided relevant information.

The designs of the braces influence their ability to reduce anterior-posterior instability (Beck et al. 1986, Hofmann et al. 1984, Mishra et al. 1989). Hofmann et al. (1984) observed that moulded supports medially and laterally as well as rigid side bars improved the stabilizing capacity of braces. Both the modified Lenox Hill and SKB brace correspond to this construction. The SKB brace may fail to reduce abnormal motion due to poor femoral containment and displacement of the tibia together with the entire brace when the lower leg is stressed.

Pistoning, brace migration, and hinge design all influence the congruency between joint and brace motions (Regalbuto et al. 1989). In our study the ECKO braces decreased anterior-posterior instability, but they do not improve performance in the anterior cruciate ligament injured patient (Tegner and Lysholm 1985).

Only the Lenox Hill brace influenced the external rotatory instability, confirming ex vivo data by Wojtys et al. (1987). Restriction of external rotation might protect the knee from further injuries, but does not compensate for an increased instability caused by rupture of the anterior cruciate ligament.

In this and a previous study (Kärrholm et al. 1989), the injured knees displayed a smaller amount of external rotation during anterior traction and simultaneous external rotation than the intact knees.

To reach the most internally rotated position, we added anterior traction to the internal torque, but recorded no stabilizing effect of the braces. Other effects of knee braces, such as increasing the stiffness of the knee (Colville et al. 1984), may be important in reducing giving-way episodes.

A functional brace should be expected to decrease the anterior-posterior instability as observed in two of the designs studied. Reduction of the internal rotatory instability is probably also beneficial because the tibia rotates internally during anterior subluxation (Kärrholm et al. 1989, Galway and MacIntosh 1980, Noyes et al. 1989); although this internal rotation may be within physiologic ranges (Kärrholm et al. 1989).

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