

# Does meniscus removal affect ACL-deficient knee laxity? An in vivo study

S. Zaffagnini<sup>1,2,3</sup> · C. Signorelli<sup>1</sup> · T. Bonanzinga<sup>1,2</sup> · A. Grassi<sup>1,2</sup> · H. Galán<sup>4</sup> ·  
I. Akkawi<sup>1,2</sup> · L. Bragonzoni<sup>1,3</sup> · F. Cataldi<sup>5</sup> · M. Marcacci<sup>1,2,3</sup>

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## Abstract

**Purpose** The purpose of the present study was to determine, in vivo, the effect of different types of meniscectomy on an ACL-deficient knee.

**Methods** Using a computer-assisted navigation system, 56 consecutive patients (45 men and 11 women) were subjected to a biomechanical testing with Lachman test (AP30), drawer test (AP90), internal/external rotation test, varus/valgus rotation test and pivot-shift test. The patients were divided into three groups according to the status of the medial meniscus. Group BH, 8 patients with bucket-handle tear of medial meniscus underwent a subtotal meniscectomy; Group PHB, 19 patients with posterior horn body of medial meniscus tear underwent a partial meniscectomy; and Group CG with isolated ACL rupture, as a control group, with 29 patients.

**Results** A significant difference in anterior tibial translation was seen at 30 grades and in 90 grades between BH and PHB groups compared to the CG. In response to pivot-shift test, no significant differences in terms of AREA and POSTERIOR ACC were found among the three groups

(n.s). Concerning the anterior displacement of the pivot shift a statistically significant differences among the three tested groups was found.

**Conclusion** The present study shows that meniscal defects significantly affect the kinematics of an ACL-deficient knee in terms of anterior tibial translation under static and dynamic testing.

**Keywords** Meniscectomy · ACL · Deficient knee · Laxity · Navigation system

## Introduction

Meniscal injuries associated with acute anterior cruciate ligament (ACL) tears are reported to range from 15 to 40 % [1]. During an ACL injury, a concomitant meniscal tear is reported to have an incidence from 25 to 45 % for the medial meniscus (MM) and from 31 to 65 % for the lateral meniscus (LM). The incidence of meniscal tears in the setting of a chronic ACL deficiency become higher, especially on the medial side. Analysis of biomechanical data, such as resulting kinematics of the knee and the in situ forces in the anterior cruciate ligament, have shown that a chronic instability determines an increase in the loading forces on the MM up to double at 30° and 90° of knee flexion [15]. More than 75 % of these lesions occur in the peripheral posterior horn body according to a prospective analysis of 575 meniscal tears by Smith and Barret [20], which considered patients who underwent ACL reconstruction. In particular, 73.3 % of the cases analysed were treated within 6 weeks from the injury.

Several in vitro studies highlighted the importance of the meniscus in limiting anterior tibial translation (ATT) in the ACL-deficient knee [2, 4, 7, 8]. Lorbach et al. [11,

✉ C. Signorelli  
c.signorelli@biomec.ior.it

<sup>1</sup> Laboratorio di Biomeccanica e Innovazione Tecnologica, Istituto Ortopedico Rizzoli, Via di Barbiano 1/10, 40136 Bologna, BO, Italy

<sup>2</sup> Clinica Ortopedica e Traumatologica I, Istituto Ortopedico Rizzoli, Bologna, BO, Italy

<sup>3</sup> Dipartimento di Scienze Biomediche e Neuromotorie, Università di Bologna, Bologna, BO, Italy

<sup>4</sup> Instituto Dr. Jaime Slullitel, Rosario, Santa Fe, Argentina

<sup>5</sup> Anestesia e terapia intensiva post operatoria e del dolore, Istituto Ortopedico Rizzoli, Bologna, BO, Italy

12] proved that suturing a meniscal tear significantly reduces the ATT to levels comparable to the uninjured state. Although meniscal preservation in ACL reconstruction in the knees with combined ACL and medial meniscus injuries have the theoretical advantage of being protective to the articular cartilage, meniscectomy remains necessary for irreparable meniscal tears. In previous clinical studies, meniscectomy combined with ACL reconstruction has been reported to result in significant pain relief and functional improvement [16, 18].

However, the effect of meniscectomy on the knee stability and rotational kinematics during ACL reconstruction is still controversial, as no sound agreement is present in the literature due to the scarceness of clinical quantitative data. Indeed, to the authors' knowledge, there are no previous *in vivo* studies that assessed intraoperatively the effect of meniscal status in an ACL-deficient knee. The purpose of this study was to determine, *in vivo*, the effect of different levels of meniscectomy on an ACL-deficient knee. The hypothesis was that medial meniscectomy would have significantly affected the kinematics, increasing the static and dynamic laxity.

## Materials and methods

Fifty-six consecutive patients (45 men and 11 women) were enrolled in the study. The inclusion criteria were acute or chronic ACL deficiency with or without an irreparable medial meniscal tear. The exclusion criteria were lateral meniscal tear, reparable medial meniscal tears, additional ligament tears or history of ACL reconstruction in the injured knee.

All the patients were operated by the same surgeon (XX). At the time of surgery, the patients were divided into three groups depending on the status of the medial meniscus. Group BH, 8 patients with bucket-handle tear of medial meniscus who have undergone a subtotal meniscectomy; Group PHB, 19 patients with posterior horn body of medial meniscus tear who have undergone a partial meniscectomy; and Group CG with isolated ACL rupture, as a control group, with 29 patients.

The mean (SD) age at surgery was 33 (10) years. The mean (SD) time from the first knee injury to the surgical procedure was 25 (39) months.

In order to evaluate preoperative joint laxity, a surgical navigation system was adopted (BLU-IGS, Orthokey, Lewes, Delaware, DE, USA), equipped with software specifically dedicated to intraoperative kinematics acquisitions (KLEE, Orthokey, Lewes, Delaware, DE, USA).

## Testing protocol

The examination protocol was performed after meniscectomy and before ACL reconstruction utilizing the method developed by Martelli et al. [12].

The surgeon manually performed the clinical kinematic tests at maximum force.

The following were analysed:

- Anterior/posterior displacement at 30° of flexion (AP30)
- Anterior/posterior displacement at 90° of flexion (AP90)
- Internal/external rotation at 30° (IE30)
- Internal/external rotation at 90° (IE90)
- Varus/valgus test at 0° (VVO)
- Varus/valgus test at 30° (VV30)
- Pivot-shift (PS) test was used to assess the dynamic laxity. It was strictly executed following the clinical grading defined by Jacob et al. [5].

In order to quantify the pivot-shift test, according to the literature [6, 12], three different parameters were evaluated: the area included by the lateral tibial compartment translation with respect to flexion/extension angle (named AREA); the POSTERIOR ACC, that corresponds to the posterior acceleration of the lateral tibial compartment during tibial reduction; and finally, the maximal anterior displacement of the lateral tibial compartment (named ANTERIOR DISPLACEMENT) [10].

The reliability of all laxity tests performed at maximum force was evaluated by the research group in previous studies [9, 13]. During the whole set of tests and reconstructions, the examiner was the same and was blind for test quantitative results in order to avoid bias in the acquisitions.

All the enrolled patients signed informed consent forms to participate in the research study approved by the Institutional Review Board (IRB approval: Prot 40/CE/US/ml) of Istituto Ortopedico Rizzoli (Bologna, Italy).

## Statistical analysis

The presence of outliers data in the kinematic test results was evaluated using the Modified Thompson Tau method before applying inference analysis. In order to obtain a small sample size in each group, a non-parametric statistical approach was required: Mann–Whitney test was applied to compare the different groups to CG. An alpha value of 0.05 was set as significant. All statistical analysis was performed using Analyse-it/Excel (Microsoft, Redmond, Washington State, USA).

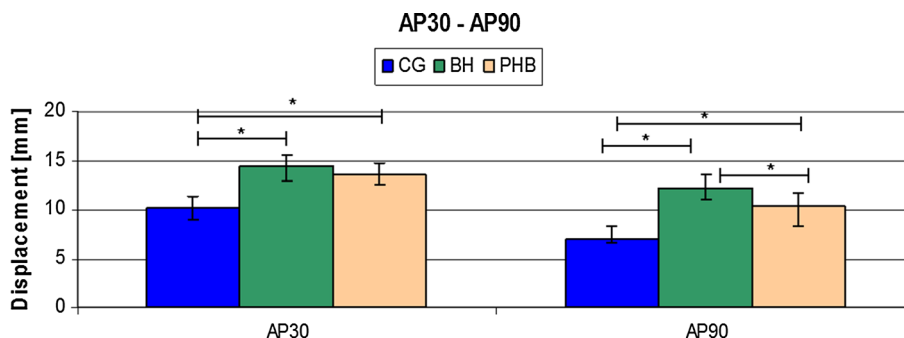
## Results

### Anterior/posterior displacement

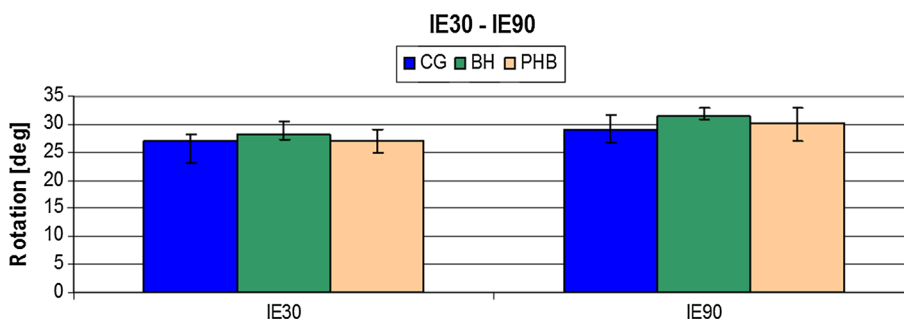
Concerning AP30, a significant ( $P < 0.01$ ) higher laxity for both BH and PHB group compared to the CG has been found. In particular, the CG showed a median value of 10.1 mm (range 8.9–11.4 mm), the BH group a median value of 14.5 mm (range 13–15.6 mm), and the PHB group a median value of 13.5 mm (range 12.6–14.7 mm). No significant difference (n.s) was observed between the two groups with meniscal tear.

Analogously, AP90 was significantly higher ( $p < 0.01$ ) in the two groups with a meniscal tear. The median value of this laxity parameter was 7.0 mm (range 6.5–8.4 mm) in the CG group, 12.2 mm (range 11.1–13.6 mm) in the BH group and 10.3 mm (range 8.4–11.7 mm) in the PHB group. The difference between BH and PHB group was significant as well ( $P = 0.03$ ) (Fig. 1).

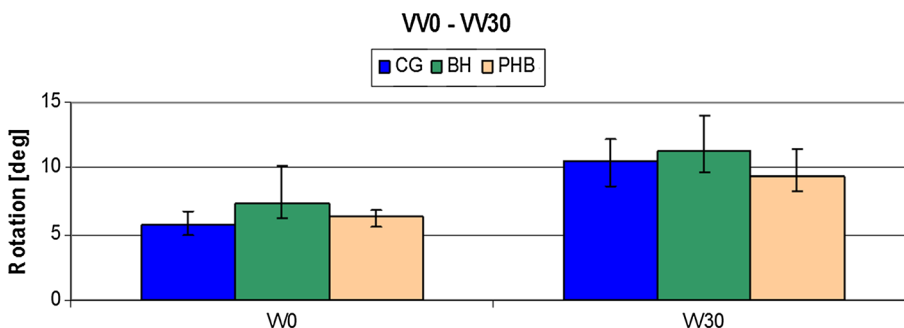
**Fig. 1** Graphical representation of anterior tibial displacement (mm) at 30° and 90° (AP30–AP90) for the three study groups: CG (control group), BH (bucket-handle) and PHB (posterior horn body)



**Fig. 2** Graphical representation of internal/external rotational laxity [°] at both 30° and 90° degree of knee flexion (IE30, IE90) for the three study groups: CG (control group), BH (bucket-handle) and PHB (posterior horn body)



**Fig. 3** Graphical representation of varus/valgus rotational laxity [°] at both 0° and 30° degree of knee flexion (VV0, VV30) for the three study groups: CG (control group), BH (bucket-handle) and PHB (posterior horn body)



### Varus/valgus and internal/external rotation

Concerning the static rotational laxity at 0°, 30° and 90° degree of knee flexion (IE30, IE90, VV0, VV30), there was no statistical differences (n.s) between the three study groups (Figs. 2, 3).

### Pivot-shift test

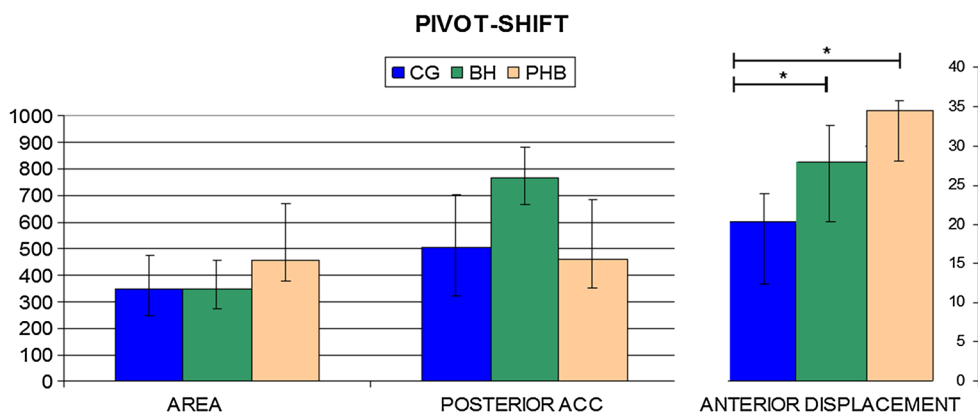
#### AREA and POSTERIOR ACC

No significant differences in terms of AREA and POSTERIOR ACC were found among the three groups (n.s).

Concerning the ANTERIOR DISPLACEMENT of the pivot-shift, a statistically significant difference among the three tested groups was found.

In particular, in the CG, the median value resulted was 20.3 mm (range 12.4–23.9 mm); in the BH group, the result was 28.0 mm (range 20.4–32.7 mm); and lastly in the PHB

**Fig. 4** Graphical representation of pivot-shift test laxity parameters: AREA, POSTERIOR ACC, ANTERIOR DISPLACEMENT. Results have been reported for three study groups: CG (control group), BH (bucket-handle) and PHB (posterior horn body)



group, resulting median value was 34.5 mm (range 28.0–35.7 mm). The comparison between CG and BH group was statistically significant ( $P = 0.04$ ) as was the difference between CG and PHB ( $P = 0.01$ ). The results have been graphically reported (Fig. 4).

## Discussion

The most important finding of the present in vivo study is that subtotal medial meniscectomy in ACL-deficient knees increases anterior tibial translation at 30° and 90° of knee flexion. Further, at deeper angles of flexion, meniscal defects due to a bucket-handle tear have significantly increased this laxity parameter compared to a meniscal defect limited to the posterior horn body. With the combined rotatory and axial loads of a pivoting manoeuvre, both meniscal defects produced a significant increase in anterior displacement compared to the control group. On the other hand, no significant change in terms of rotational laxity was observed.

The importance of the medial meniscus as a secondary stabilizer in the ACL-deficient knee is well studied in in vitro conditions. Some authors showed that meniscectomy in an ACL-deficient knee increased instability. Seon et al. [17], in an in vitro study, detected that subtotal medial meniscectomy increased anterior tibial translation at all flexion angles under anterior tibial load. This is consistent with the present work and previous studies in the literature [2, 8, 11, 19], as well. However, some authors did not observe an increase in knee laxity after meniscectomy [15].

The data of the present work slightly differ from the in vitro paper by Musahl et al. [14]. They investigated knee laxity parameter by means of Lachman test under 68 N load and mechanized pivot-shift test on ten fresh-frozen hip-toe lower extremities. Similarly, to the current paper, laxity evaluation was performed with a navigation system. Both laxity testing was performed, first in ACL-deficient knees, and after medial and lateral meniscectomies. They showed

that medial meniscus is a significant secondary restraint to anterior tibial translation, but did not significantly affect the anterior translation of the lateral compartment during the simulated pivot shift in ACL-deficient knees. A reason for this disagreement might lay in the differing set-up; the young population of the current study is likely to have better tissue quality than fresh-frozen specimens. Therefore, it is expected that laxity's changes are easier to detect in an in vivo set-up. Lorbach et al. [11], testing cadaveric specimens, found that partial or total meniscectomy of the medial meniscus determine a significant impact on knee kinematics in the ACL-deficient knee evaluated by Lachman and pivot-shift test, whereas the repair of the meniscus was able to reduce it, similar to the ACL-deficient knee with intact meniscus.

Papageorgiou et al. [15], in an in vitro study, measured the kinematics of the knee and the in situ force in the ACL-reconstructed knee after medial meniscectomy. They measured the anterior tibial translation under a combined 134 N anterior and 200 N axial compressive tibial load for several testing conditions using a robotic/universal force-moment sensor testing system. They did not find any difference in terms of tibial translation, but they reported that after medial meniscectomy, the force in the ACL graft increases between 30 and 50 %. In consequence, they suggested that the ACL replacement grafts may be subjected to higher risks of failure.

Wu et al. [22] performed an in vivo evaluation on a series of patients undergoing different degrees of meniscectomy combined with an ACL reconstruction. They did not find any difference in terms of anteroposterior laxity. However, the instrumental laxity assessment was performed with the arthrometer KT2000 which has lower precision compared to a navigation system. Moreover, the patients that underwent meniscal resection achieved a worse clinical result in terms of subjective scores and activity level compared to the group that underwent isolated ACL reconstruction.

Chen et al. [3], in an in vitro porcine study, analysed three different conditions using a robotic system (CASPAR

Staubli RX90, Orto MAQUET, Germany): intact medial meniscus, posterior or anterior horn of medial meniscus resection, and total medial meniscectomy.

They concluded that medial meniscectomy had no effect in anterior tibial translation, but the posterior horn medial meniscectomy increased the internal rotation, while the anterior horn medial meniscectomy increased the external rotation.

Results could be affected by the fact that porcine knee joints never reach full extension arresting their range of motion at about 30° of flexion.

Also evaluating ACL-intact knees, Spang et al. [21] showed that the removal of the meniscus led to a significant increase in anterior tibial translation at all knee flexion angles. This is in contrast to the in vitro study of the effect of meniscectomy on the biomechanics of the normal knee, by Levy et al. [8], in which no increase in the tibial displacement after complete medial meniscectomy was found.

The lower value of lateral tibial displacement in the BH group compared to the PHB once during PS test is in the authors' opinion generated by an alteration of the centre of rotation due to the greater amount of the meniscal tissue removed. Such tissue removal can move the centre of rotation forward, reducing the amount of anterior displacement detected during the test.

In the setting of primary ACL reconstruction, these findings could help the clinician to be aware of the highest pre-operative laxity of the meniscus deficient, in order to eventually consider customized surgical solutions to address this unfavourable condition.

There are some limitations to the present study. The first is the difference in meniscus tear patterns and extension among the studied subjects. While in in vitro study, it is possible to control the precise size of the lesions.

Another limitation is that the laxity tests were performed by a navigation system, and not under force and displacement control modes. Anyway, the repeatability of the performed test has been already tested in previous studies showing encouraging results [9, 13, 23].

Despite the previously reported limitations, to the best of the authors' knowledge, this is the first in vivo study performed with an objective tool such as navigation system that investigated the effect of different types of meniscal defects on an ACL-deficient knee.

## Conclusion

The present work proved that meniscal defects significantly affect the kinematics of an ACL-deficient knee in terms of anterior tibial translation under static and dynamic testing. These results point out the importance of menisci in joint behaviour. Future clinical studies are needed to detect the

long-term effect of these zero-time kinematic differences. The authors advocate the development of high precision objectives and non-invasive tools for laxity's evaluation in clinical settings.

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