千葉大学学位申請論文

Joint Position Sense following Partial Medial Meniscectomy
(内側半月板部分切除術後の関節位置覚)

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Ⅰ Introduction

The complex kinematics of the knee depends on the mechanical stability and the dynamic interaction between the central nervous system and the joint. Proprioception gives information about movement and joint position sense and is important for muscular control of the knee.[1]

Although all structures around the knee (i.e. skin, muscles, ligaments, capsule, tendons, and menisci) may contribute to the proprioceptive role of the joint, proprioceptive functions of the anterior cruciate ligament has been studied extensively previously.[2] Most studies have concluded that proprioception is lost in the knee with a deficient anterior cruciate ligament,[3] and that even after several years following anterior cruciate ligament reconstruction, proprioception is still lost partially.[4]

The two wedge-shaped pieces of cartilage between the femur and tibia acting as “shock absorbers” are called meniscus, and these also play an important role in proprioception due to the presence of mechanoreceptors in the anterior and posterior horns.[5] Meniscal tears are among the most common knee injuries in the young and elderly, and partial meniscectomy has been performed, with good short and middle term results.[6] However, arthritic changes in the long term follow up after meniscectomy is also reported.[7] Some have attributed this to increased contact pressures from the smaller surface area, as well as from the loss in proprioceptive feedback from the menisci.[8]

Joint position sense, a component of proprioception, represents the ability to reproduce a previously given limb position without visual feedback. Different methods have been used previously to test joint position sense and various authors have performed joint position sense tests in the supine and prone positions. Varying results have been observed and this has been attributed to the poor reliability of the tests.[9]

The purpose of this study was 1) to report the inter- and intra-observer reliability of knee flexion angle measurements for joint position sense testing using a bipolar angle sensor, 2) to report the difference of joint position sense in medial meniscus torn knees in supine/standing positions, 3) to report the difference of joint position sense before and after partial medial meniscectomy in the standing position. For each purpose, our hypothesis was 1) that both the inter- and intra-observer reliability using the bipolar angle sensor is high, 2) that joint position sense of medial meniscus torn knees is superior in the standing position, and 3) that joint position sense is superior before partial meniscectomy .

Ⅱ Materials and Methods

All tests were approved by the hospital ethics committee and carried out in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent amendments. All volunteers gave their informed consent for each test.

Goniometer System

For all tests, we used a MLTS700 electronic goniometer (AD Instruments, U.S.A.) for our measurements (Fig 1). The specifications of this sensor were; full scale range:±1.0V for ±90 degree joint movement, output voltage M(V) for straight sensor: 2.5V±0.2V, accuracy:±2% full scale, resolution: 0.05V. A straight sensor in ±0 degrees measured an output M(V) of +2.5(V), and ±0.5(V) corresponded to ±45 degrees, while ±1(V) corresponded to ±90 degrees. Thus, the output voltage M(V) and the knee flexion angle N(degrees) had a relationship of $M=N/90+2.5$ when N was between -90 and +90. This sensor was fixed on the thigh and calf with soft elastic taping under minimal tension to measure the angle between the femoral and fibular axes. The femoral axis was defined as a line drawn from the bony landmark of the greater trochanter to the bony landmark of the lateral epicondyle, and the fibular axis was defined as a line drawn from the bony landmark of the fibular head to the bony landmark of the lateral malleolus (Fig 2). The MATLAB version 7.1 software (Mathworks, Inc., U.S.A.) on a Windows XP Professional operated Dell INSPIRON 6000 computer was used for recording of goniometer data. Each measurement was performed three times and the mean value was utilized for analysis.

Inter- and Intra-observer Reliability test

Four healthy male volunteers with an average age of 30.5 years (range 24-39 years), consisting of 2 physiotherapists, one orthopaedic surgeon, and one medical student were selected. No volunteer had previous knee history of pain, mechanical symptoms, or surgery. These volunteers performed knee flexion reproduction tests for 45 and 90 degrees in the supine position and 45 degrees in the standing position. Prior to the tests, we did not perform teaching sessions to remember the real 45 and 90 degree flexion angles, since our purpose was to measure the subjective joint position sense of each volunteer. Since the maximum knee extension angle varied between volunteers, they were asked to flex 45 and 90 degrees from the possible maximum extension angles. The volunteers performed all the tests blindfolded to shut out visual feedback from the surrounding view which has been reported to improve knee joint position sense.[9] An orthopaedic surgeon with 1 month of experience using this angle sensor and a physician assistant with 3 years of experience performed the measurements individually without being notified of the study purposes. After the first examiner fixed the sensors to the thigh and calf and completed all the measurements (45 degrees supine, 90 degrees supine, 45 degrees standing), the sensors were removed. The second examiner repeated the tests, starting over from fixation of the sensors. Same tests in the same volunteers were repeated by the examiners in the same order after one week to evaluate intra-observer reliability between these two time periods.

Comparison between Supine and Standing Positions in Patients with Medial Meniscus Tears

We performed this test as a prospective study and our inclusion criteria were (1) patients who presented to our clinic between June 2009 and June 2010 with symptoms of continuous catching, knee pain, or swelling, (2) with a diagnosis of medial meniscus tear on physical examination and magnetic resonance imaging, and (3) scheduled for arthroscopic surgery of the knee. The exclusion criteria were (1) age under 25 years, (2) clear traumatic episodes prior to experiencing knee symptoms, (3) previous knee surgery, (4) concomitant anterior cruciate ligament pathology, or (5) grade 3-4 cartilage lesions. Patients with concomitant lateral meniscus tear, degenerative tear of the medial meniscus, or osteoarthritic changes were not excluded. The final study group was composed of 7 knees in 5 men and 2 women, with an average age of 49.7 years (range 26–62 years).

Tests were conducted on the day before partial meniscectomy. Patients were asked to flex their knee 45 degrees from the extended starting position and hold in supine and standing positions (Fig 3). They were advised to flex their knees over their second toe, and not in a knee-in toe-out position. Prior to the tests, we did not perform teaching sessions to remember the real 45 degree flexion angles, since our purpose was to measure the subjective joint position sense of each subject. Since the maximum knee extension angle varied between volunteers, they were asked to flex 45 degrees from the possible maximum extension angles. The patients were blindfolded during the evaluation to prevent visual feedback.[9] Evaluation was conducted by a physician assistant who was not involved in any of the diagnosis or treatment of the patient.

Comparison between Pre- and Post-operative Joint Position Sense in the Standing Position

We performed this test as a prospective study and our inclusion criteria were (1) patients who presented to our clinic between June 2009 and July 2011 with symptoms of continuous catching, knee pain, or swelling, (2) with a diagnosis of an isolated middle and/or posterior medial meniscus tear on physical examination and magnetic resonance imaging (Fig 4), and (3) scheduled for an arthroscopic partial meniscectomy of the medial meniscus. Our exclusion criteria were (1) age under 25 years, (2) clear traumatic episodes prior to experiencing knee symptoms, (3) previous knee surgery, (4) bilateral knee symptoms, (5) anterior cruciate ligament pathology, (6) lateral meniscus tears, (7)grade 3-4 articular cartilage lesions, and (8) obvious spur formation of the joint. Joint space narrowing on radiographs was not an exclusion criteria because this is not only a sign of osteoarthritic change and articular cartilage pathology, but also a sign of medial meniscus pathology. The final study group was composed of 8 knees in 6 men and 2 women, with an average age of 61.3 years (range 29–80 years).

Operative Technique

Arthroscopic partial meniscectomy was performed by 2 fellowship-trained, board certified orthopedic surgeons with similar criteria for surgery; i.e., patients preferring arthroscopic procedures for previously stated symptoms. Comparable surgical techniques were utilized. A high anterolateral portal and standard anteromedial portal were created, and a shaver and meniscal punch were used to achieve a stable rim and remove any unstable fragments of the tear. A smooth border was created to contour the edges.

Post-operative Rehabilitation Protocol

Full weight bearing and range of motion from 0 to 120 degrees flexion was achieved by 2 weeks post-operatively. Full preoperative range of motion was achieved by 4 weeks post-operatively. Hard labor and sports activities were permitted after 3 months if full muscle strength and full range of motion were achieved.

Evaluation was conducted by a physician assistant who was not involved in any of the diagnosis or treatment of the patient. Tests were performed one day to one week prior to surgery, and at 1 month, 6 months, 1 year after surgery. Patients were asked to flex their knee 45 degrees from the extended starting position and hold in the standing position. They were advised to flex their knees over their second toe, and not in a knee-in toe-out position. Prior to the tests, we did not perform teaching sessions to remember the real 45 degree flexion angles, since our purpose was to measure the subjective joint position sense of each volunteer. Since the maximum knee extension angle varied between volunteers, they were asked to flex 45 degrees from the possible maximum extension angles. The patients were blindfolded during the evaluation to prevent visual feedback.[9]

Statistical Analysis

The intraclass correlation coefficient (ICC) for inter- and intra-observer reliability was calculated with a two-way mixed effects model. The t-test was performed to compare the different values with the level of significance set at $P<0.05$. Statistical analysis was carried out by means of the SPSS Statistics ver.17.0 for Windows (SPSS Japan Inc., Tokyo, Japan).

Ⅲ Results

No post-operative extra-articular or intra-articular complications were encountered in any of our series.

Inter-observer ICC between the 2 evaluators was 0.959, and intra-observer ICC for the less experienced evaluator and the experienced evaluator was 0.959 and 0.990, respectively.

Mean M(V) values of joint position sense error in the supine and standing positions in medial meniscus torn knees are shown in Table 1. Our results showed that pre-operative joint position sense in the standing position was significantly superior compared with the supine position (Fig 5).

Mean M(V) values of pre- and post-operative joint position sense error at 1 month, 6 months, and 1 year after surgery are shown in Table 2. At all time periods post-operatively, joint position sense was worse in comparison with pre-operative values. Although joint position sense showed a tendency to improve after 6 months, it was still significantly abnormal at 1 year following surgery (Fig 6).

Ⅳ Discussion

Our study showed that this method of measuring joint position sense using an angle sensor wrapped around the thigh and calf with elastic taping under minimal tension was high in terms of inter- and intra-observer reliability and that this is a preferred method for such purposes.

Various authors have studied on joint position sense of the knee following anterior cruciate ligament reconstruction and total knee replacement, and different results have been reported.[10] We believe this difference in outcome is due to the different measurement methods by these authors. Although the authors performed the tests with the leg in a splint to neutralize cutaneous sensation, the muscle nerves were not blocked in these studies, and pressure placed on thigh and calf muscles in the sitting position and from the tight splint was possibly a source of measurement differences due to the role of intramuscular receptors.[11] We believe that placing pressure on thigh and calf muscles may become a source of bias in accurately measuring knee joint position sense due to proprioceptive feedback from muscle afferents.[12] This is supported by our data that joint position sense was more inaccurate in the supine position pre-operatively. To prevent such bias, recent studies have reported on using smartphones handheld on the bony landmarks. The smartphones were equipped with accelerometers, magnetometers, and gyroscopes to measure joint flexion angles.[13,14] Although these studies have reported good inter- and intra-observer reliability, accuracy of the smartphones was not specified and holding the system throughout the measurement was unrealistic for measuring joint position sense. Thus, reproducibility of the measurements using smartphones remains controversial. Our tests were performed using a sensor with specifications on accuracy and resolution and we wrapped this sensor around the thigh and calf with soft elastic taping under minimal tension to minimize cutaneous sensation. Instead of placing the sensor on the bony landmarks directly, we placed our sensors on the femoral and fibular axes since the femoral and fibular axes were drawn from two bony landmarks each and easily reproducible.

It has been previously reported that there is no joint position sense difference between meniscectomy performed knees and healthy knees in lesser degrees of flexion.[15] We believe the reason for this non-significance in lesser angles of flexion was due to the little pressure placed on the posterior meniscus in shallow flexion. Nerve fibers and sensory receptors exist in the posterior horn of the meniscus, and the posterior horn height is reported to decrease even at 30 degrees of knee flexion.[16] Thus, we believe that for accurate measurement of joint position sense, 45 degrees of knee flexion in the standing position is appropriate.

Our study has its limitations. For the inter- and intra-observer reliability tests, we could not prevent allocation bias, due to the availability of healthy volunteers. As for assessment bias, this was prevented by not explaining the study purposes to the examiners. In the pre-operative comparison between supine and standing positions, and in the comparison of pre- and post-operative joint position sense in the standing position, the number of patients included was relatively small due to the strict inclusion and exclusion criteria. Performance bias needs consideration since the partial meniscectomy procedure was performed by two senior surgeons. Although the physician assistant who evaluated the patient was not involved in any of the diagnosis or treatment of the patient, he was able to gain information on whether the patient had undergone surgery from the skin incision, and this could possibly be a source of assessment bias.

Ⅴ Conclusions

Both the inter- and intra-observer reliability for joint position sense testing using a robust, bipolar angle sensor wrapped around the thigh and calf with elastic taping under minimal tension were high. Joint position sense at 45 degrees of knee flexion in the standing position was significantly better compared with the supine position in medial meniscus torn patients. Joint position sense at 45 degrees of knee flexion in the standing position worsened after partial medial meniscectomy. Partial medial meniscectomy seems to have an adverse effect on knee joint position sense.

Declaration of conflicting interests
The authors had no conflict of interest to declare in relation to this article.

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Figures

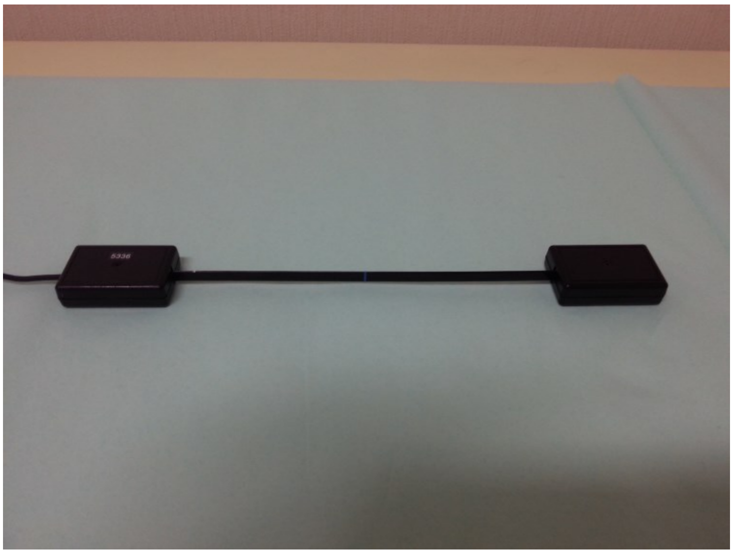

Fig 1

Electronic goniometer used in this study for measuring knee flexion angles. This was a robust, bipolar angle sensor designed for single degree of freedom joints such as the knee.

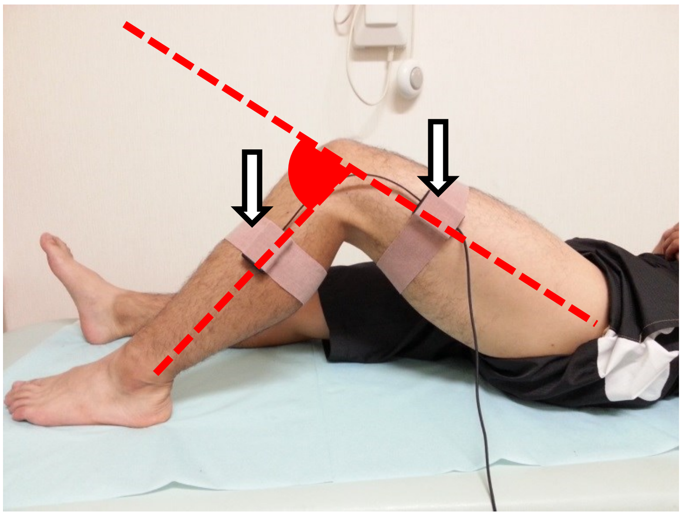

Fig 2

The femoral axis was designed as a line connecting the bony landmarks of the greater trochanter and the lateral epicondyle. The fibular axis was designed as a line connecting the bony landmarks of the fibular head and the lateral malleolus. The angle between the two axes was measured by the goniometer. Arrows indicate placement of goniometer.

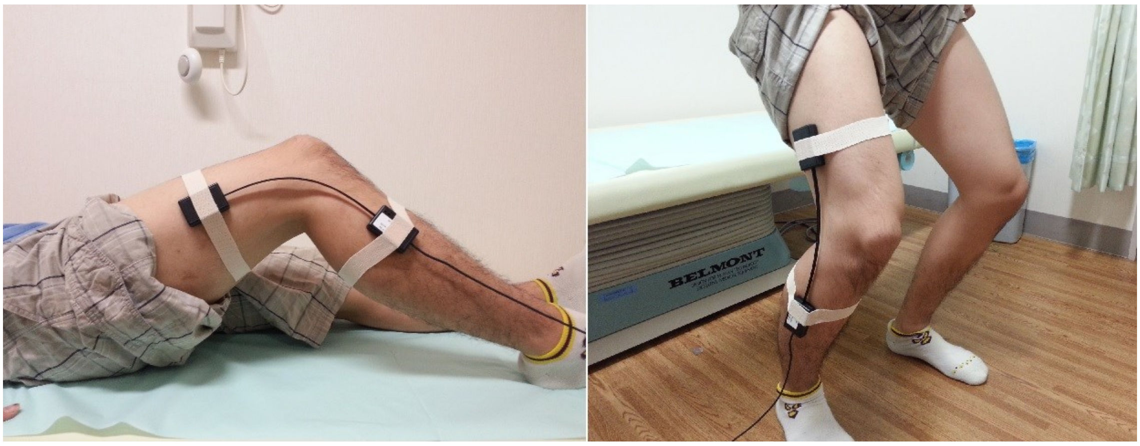

Fig 3

Joint position tests conducted in the supine (left image) and standing (right image) positions. In the supine position, knee flexion was performed by sliding the heel on the bed. In the standing position, patients were advised to flex their knees over their second toe, and not in a knee-in toe-out position.

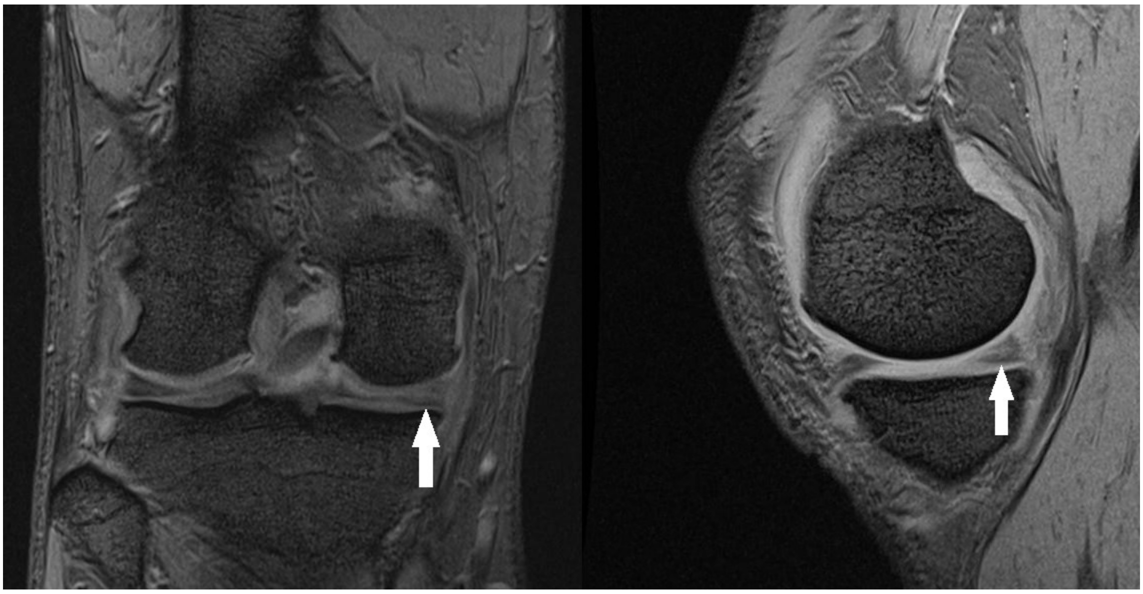

Fig 4

Coronal (left image) and sagittal (right image) magnetic resonance image of a middle to posterior medial meniscus tear(white arrow).

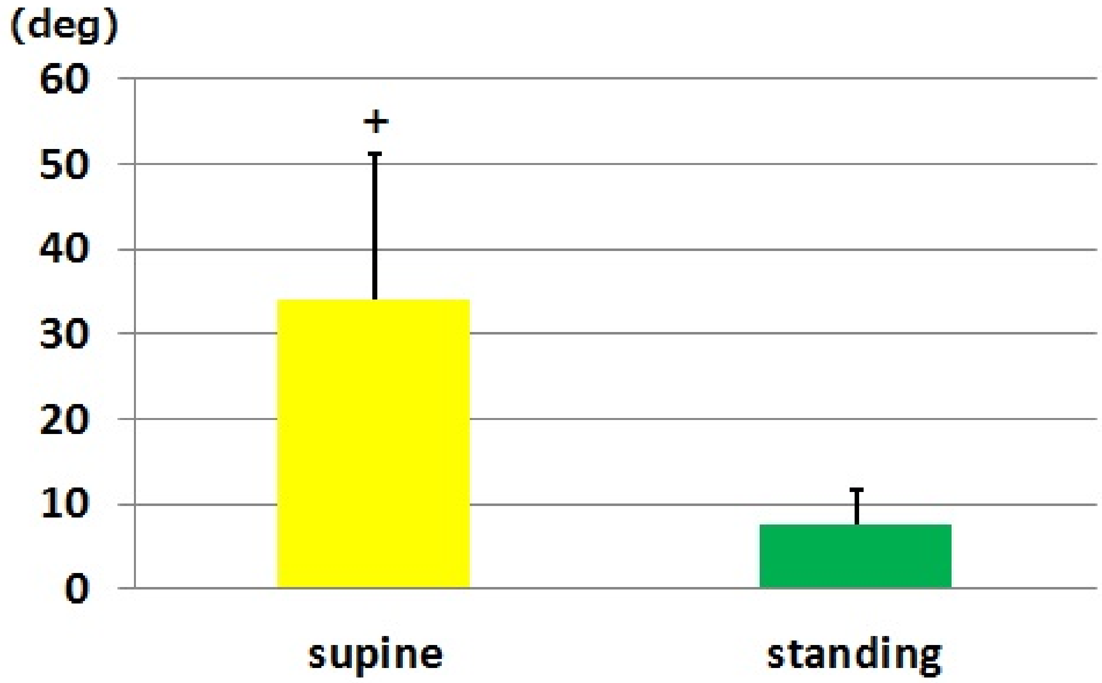

Fig 5

Joint position sense error in the supine and standing positions in medial meniscus torn knees. Values indicate average±SD. Joint position sense in the standing position was significantly better than the supine position. + P<0.01

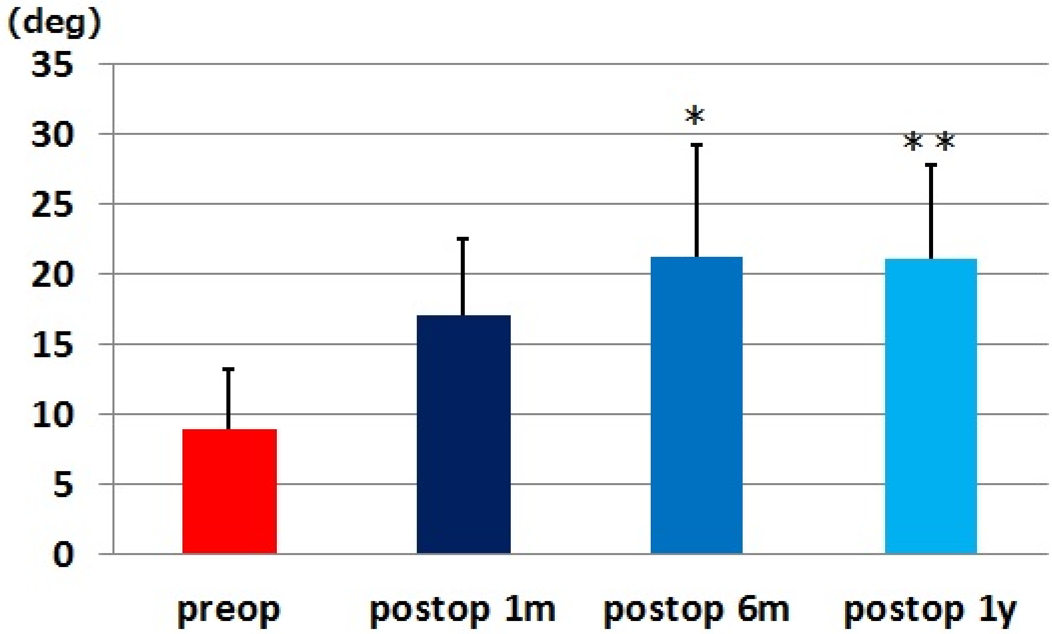

Fig 6

Pre- and post- operative joint position sense error in the standing position. Values indicate average±SD. Joint position sense was worse after partial medial meniscectomy, especially at 6 months. It was still significantly abnormal at 1 year following surgery.

* P<0.005, ** P<0.001

Tables

Table 1

patient	supine	standing
1	0.24	0.08
2	0.39	0.11
3	0.04	0.12
4	0.36	0.04
5	0.62	0.11
6	0.47	0.13
7	0.53	0.02

Table 2

patient	preop	postop 1m	postop 6m	postop 1y
1	0.05	0.16	0.28	0.23
2	0.11	0.22	0.27	0.25
3	0.14	0.19	0.29	0.37
4	0.08	0.1	0.04	0.1
5	0.16	0.18	0.31	0.23
6	0.15	0.29	0.18	0.25
7	0.07	0.24	0.24	0.24
8	0.04	0.14	0.28	0.21

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