

Influence of the Varus-Valgus Instability of the Contact of the Femoro-Tibial Joint

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INTRODUCTION

Knee joint instability may occur in rupture of ligaments, especially of the anterior cruciate ligament (ACL) (Inoue et al, 1987). Also in Charcot's joint, with loss of synergistic reflexes and deep sensation loss, the muscles and stretched ligaments cannot retain normal alignment and stability of the joint. This in turn results in faulty weight bearing with excessive stress upon the articular surfaces and in destruction of the joint (Katz et al, 1961). To assess the changes in articular surface contact of the unstable knee joint, the contact pressures of the femoro-tibial joint with varus or valgus alignment were measured using a newly developed system.

MATERIALS AND METHODS

For measurement of the contact pressure on the tibial plateau under various loads, six fresh knee specimens from cadavers were studied. Their ages ranged from 15 to 51 years (mean age = 32.5 years), while the body weights ranged from 40 to 66 kg (mean weight = 57.6 kg). Four were from males and two were from females. None of them had any degenerative articular changes macroscopically. Prior to testing, the specimens were stored at -20°C . When required, they were gradually thawed at room temperature. Following defrosting, the femoral and tibial bone shafts were cut 10 cm below and above the joint line respectively. All the muscular tissue was removed from them before being set into special holders using gypsum. The capsule, ligamentous structures and patella were preserved intact until immediately prior to testing.

The system employed to measure contact pressures was composed of miniature transistor pressure transducers (ITOYODA-PMS-100H) and Buldon tube pressure gauges (YAMAMOTO-100). They were connected simultaneously to the pipes (1.5 mm diameter) inserted in the cartilage of the tibial plateau from the underlying subchondral bone (Figure 1) and back flashed pressure from the contact surface was led to them. Stress concentrations on the cartilage layer were avoided by a minimal protrusion of the pipes into the cartilage layer within 1.0 mm. This was confirmed by insertion of pressure sensitive sheets (Prescale by Fuji Film) between the articular surfaces. The load up to four times of the body weight (2700 N) was applied periodically, i.e., four seconds loading and two seconds unloading. The maximum compressive load was based on the calculation of Morrison (1970). By loading the specimen in this manner, long-term creep deformations due to fluid expression were avoided (Mow et al, 1984). Pressure was transformed by the miniature transistor pressure transducer to the electrical sign which was amplified and recorded by a storage oscilloscope. The data from Buldon tube pressure gauge were recorded by video apparatus.

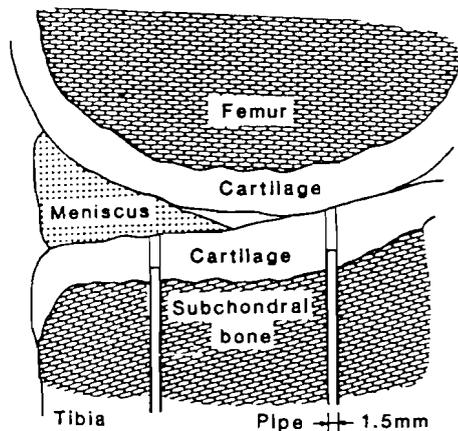


Fig. 1. Location of the pipes in the tibia.

The tibial component and holder were mounted to an auto-alignment device. This allowed anterior-posterior, medial-lateral and proximal-distal displacement, and also varus-valgus angulation and tibial axial rotation enabling natural alignment of the knee joint. The femoral component and holder were attached to the cross head of a pneumatic

loading frame via a linkage enabling the joint to be flexed through 0-45° in intervals of 7.5°.

At the extended position of the knee joint, the tibia was freed under the load of 900 N. Then the position was allowed to assume its natural position of varus-valgus alignment. Deviations from the natural position were regarded as varus or valgus angles respectively. Once established, the varus-valgus angulation and the rotational position of the tibia were maintained throughout the experiment. The contact pressures were then measured. Further measurements of the contact pressures were made during identical cyclic loading following total meniscectomy. During all testing, physiological saline was used as a lubricant and also as a pressure medium. Saline was also used to ensure the hydration of the specimen during the experiments. The whole system is shown in Figure 2.

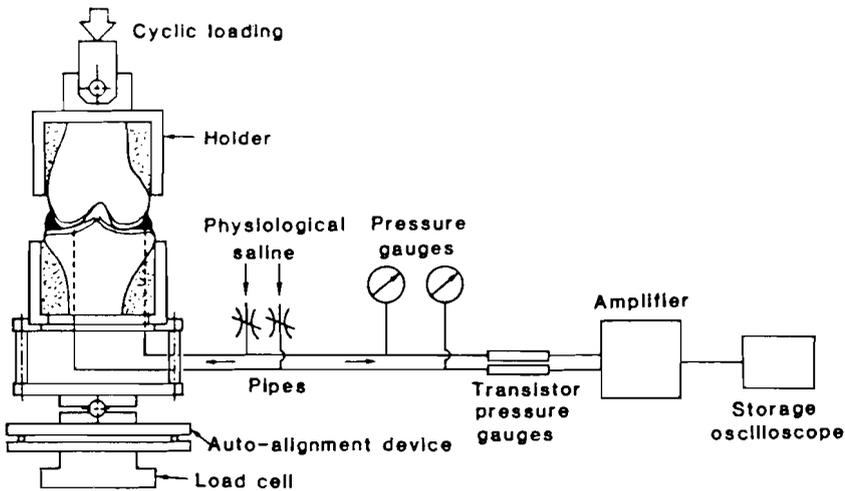


Fig. 2. Whole system of the experimental apparatus.

RESULTS

1. The contact pressures at full extension with intact menisci: Figure 3 shows the changes in contact pressure developed on the tibial plateau of specimen No. 5. The numbers in Figures indicate the positions of the inserted pipes. The pressures on the cartilage uncovered by the menisci (Nos. 1 and 2) increased roughly in proportion to load, whereas those on the cartilage covered by the menisci (Nos. 2, 3 and 6) generally increased with load. With increasing varus alignment, the contact pressures on the

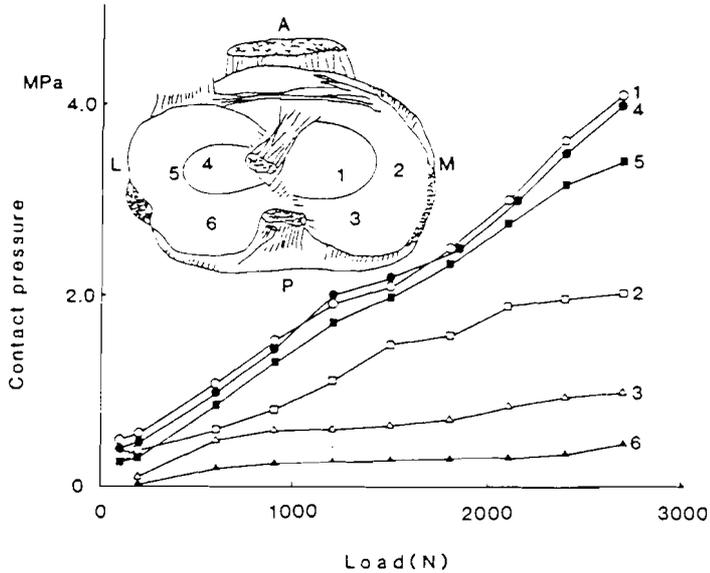


Fig. 3 Contact pressures on the tibial plateau at full extension with intact menisci (Specimen No. 5, Male, Age 38, Body weight 61 kg., left knee).

medial plateau uncovered by the meniscus increased and those on the lateral plateau decreased, showing no contact at varus 5° (Figure 4). In contrast with this, at valgus alignment the pressures on the lateral plateau showed high values.

2. The contact pressures at full extension without menisci: After total meniscectomy the contact pressures at position Nos. 1 and 4 increased rapidly with load and peak pressures showed significantly higher values than those developed with intact menisci (Figure 5). Figure 5 also shows the contact pressures on the medial plateau at varus 5° and on the lateral plateau at valgus 5° respectively. Table 1 summarized the peak contact pressures obtained for areas of the tibial plateau uncovered by the menisci, with intact menisci and following total meniscectomy.

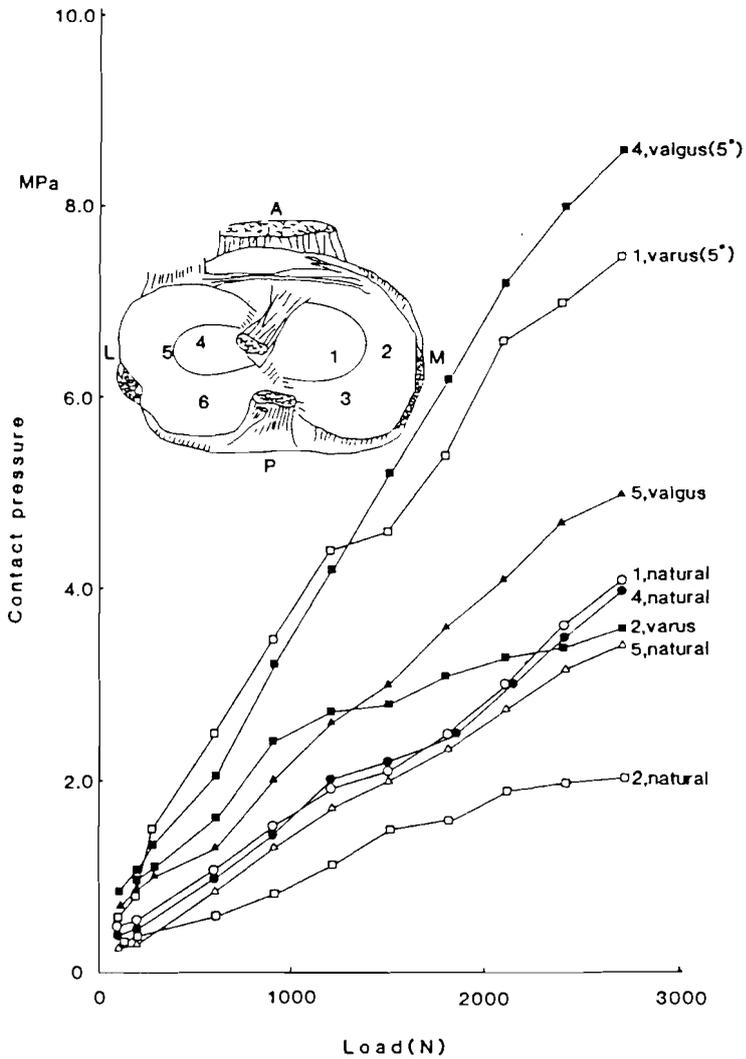


Fig. 4 Contact pressures on the tibial plateau at natural, varus and valgus alignments with intact menisci, at full extension (Specimen No. 5).

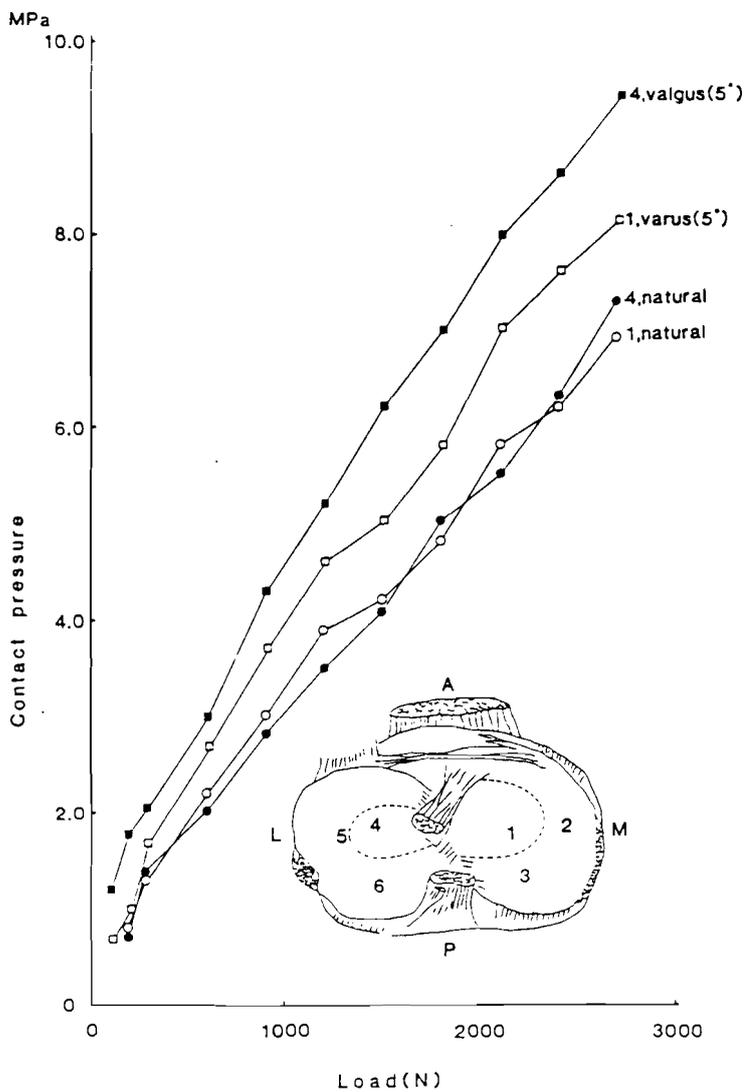


Fig. 5 Contact pressures on the tibial plateau at natural, varus and valgus alignments without menisci, at full extension (Specimen No. 5).

TABLE 1

Mean values and standard deviation of peak contact pressures. Applied load: 2700 N. n=6.

	Medial side (MPa)	Lateral side (MPa)
With intact menisci		
Natural alignment	4.01±0.52	4.12±0.65
Varus alignment (5°)	7.32±0.60	0.41±0.18
Valgus alignment (5°)	0.00	7.83±0.71
Without menisci		
Natural alignment	6.74±0.79	7.36±0.98
Varus alignment (5°)	8.12±0.93	0.00
Valgus alignment (5°)	0.00	9.23±1.02

DISCUSSION

In our investigations, for all the tests with intact menisci, the peak contact pressures on the medial plateau at varus alignment and on the lateral plateau at valgus alignment showed significantly high values, being comparable to those at natural alignment of the knee following meniscectomy. This means that the articular surfaces of the unstable knee with the intact menisci are likely to be exposed to excessive stress locally as following meniscectomy. The findings that transection of the ACL in dogs gave rise to instability of the knee which led to some proliferative and degenerative changes both in the articular tissues and in the menisci, and the notes of a close relationship between instability and the growth of osteophytes (Marshall and Olsson, 1971) are consistent with our results. Generally, tension of the ligament, the joint surface congruency, the menisci and the synergistic activity of all muscular units around the knee joint contribute to knee stability. Once one of the elements becomes disable, a knee instability probably occurs more or less. Apart from Charcot's neuropathic arthropathy, one of the main causes of joint instability is insufficient ligaments. Experimental work by Grood et al (1981) demonstrated that the medial collateral ligament (MCL) was the primary restraint, providing greater than one half of the total restraining moment and the posterior part of the capsule and the cruciate ligaments are important secondary restraints. Further, the functional deficit of the MCL in valgus alignment was compensated for by the remaining

structures, especially by the ACL. Thus the initial healing process of the injured MCL can take place without much mechanical disturbance because of the existence of an intact ACL (Inoue et al, 1987).

Conversely, Seering et al (1980) noted that the ACL proved of no importance to valgus instability at extension, but found it to be of relatively little importance in 30° of flexion. Almost the same findings were found by Nielsen et al (1984), who noted that after sectioning the ACL, the MCL and the posterior capsule, there was still complete valgus-varus stability in the joint at extension. Warren and Marshall (1978) presented high incidence of meniscal injuries in the chronic ACL insufficient knee, involving some 60 per cent. From the results of the present study of high contact pressures on the cartilages covered by the menisci at varus or valgus alignment, and from the results by Gerber and Matter (1983) that the instant-center pathway in acute ruptures of the ACL was found to have a specific abnormality, it would appear that one of the causes of meniscal injuries is the instability, namely, repetition of antero-medial or antero-lateral rotatory subluxation of the tibia. This is the same mechanism of injury as that in acute meniscal injuries. Also, in patients with insufficient ACL, medial meniscectomy appeared to increase the symptoms of instability (Warren et al, 1983). Furthermore, when the ACL was sectioned first and then medial meniscectomy was performed, a dramatic increase in anterior tibial displacement was noted (Levy et al, 1982). To make matters worse, the fact that the articular surfaces of the unstable knee without the menisci suffer exceedingly high contact pressures were confirmed in the present study.

From these findings, in the ACL — insufficient knee, total meniscectomy should be avoided if possible and ligament reconstruction, especially that of the ACL, should be performed.

SUMMARY

A newly developed system was applied to measure the contact pressures on the tibial plateau.

1. With the menisci intact, the peak contact pressures showed significantly high values whether the alignment was varus or valgus, being comparable to those at neutral alignment of the knee without the menisci.

2. Without menisci, the articular surfaces suffered much higher contact pressures than those with intact menisci at varus or valgus alignment.

3. These facts mean that the articular surfaces of the unstable knee are likely to be exposed to excessive stress whether the menisci are intact or not.