GAIT ANALYSIS OF PATIENTS AFTER DIFFERENT TREATMENTS OF ACL RUPTURED KNEES

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INTRODUCTION: The disruption of the anterior cruciate ligament (ACL) is treated by different techniques. On the basis of the individual indication, a patellar tendon autograft reconstruction, an augmented repair or a non-surgical treatment is used. In the case of the non-surgical treatment a substitution of the joint stabilizing ACL-function by an additional neuromuscular mechanism is possible (Eckardt 1994). Different results are reported with regard to the relationship between the type of treatment and long-term risks of degenerative osteoarthritis (Friederich 1993).
Human gait can cause an increase in osteoarthritis if the normal mechanical or neuromuscular functions of the knee joint are disturbed. Therefore detailed knowledge about the influence of the treatment on gait parameters during the rehabilitation process is very important. Berchuk et al. (1990) report about a "quadriceps avoidance pattern" during the gait of non-surgically treated patients. This includes a reduced knee flexion during midstance for the purpose of reducing quadriceps activity and the anterior displacement of the proximal end of the tibia. Timoney et al. (1993) observed a similar effect in patients treated with patellar tendon autograft reconstructed knees, within the first 12 post-surgical weeks.
The purpose of the present study was to evaluate, by means of gait parameters, the rehabilitation of two surgically treated groups and one non-surgically treated group of patients after disruption of the ACL. The three groups are compared with a group of normal controls.

METHODS: All investigated patients and controls are comparable regarding sports activities (leisure sports), age (27 +/- 7 years) and physical attributes (height 176 +/- 8 cm, weight 75 +/- 13 kg). Of the four groups one included 35 patients treated with a patellar tendon autograft reconstruction, another consisted of 15 patients treated with an augmented repair, the third 19 non-surgically treated patients and the fourth 30 non-patients (controls). All patients completed a complex post-surgical rehabilitation including mobilization training, gait training, proprioreceptive training, endurance training and physical therapy. The non-surgically treated group completed the same activities directly after occurrence of the disruption.
The surgically treated groups underwent the gait analysis one year post-surgically and the non-surgicals one year after the occurrence of the disruption. The technical equipment consists of two force plates for measuring the ground reaction forces (Kistler, Kistler AG Wintherthur, CH) and one optoelectronic system for the registration of the kinematic characteristics (Primas, Delft Motion Analysis, Delft, NL). The external joint moments can be calculated using kinetic and kinematic parameters. A plan of the gait lab is shown in Figure 1, further technical details are described by Schmalz et al. (1998).
All patients and controls were instructed to walk with a self-selected even speed through the region of measurement. For the purpose of evaluation only mean values from approximately 10 single trials are used for all gait parameters.

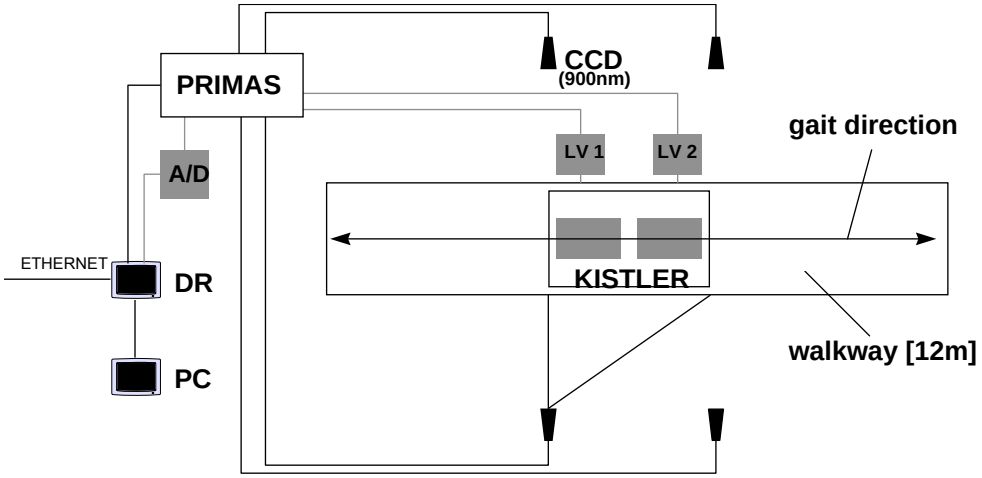

Fig. 1: Principle of the used gait lab (LV1,2: Force plate amplifiers; A/D: Analog-Digital-Converter; DR: Measuring computer; PC: Computer for data processing)

EVALUATION PARAMETERS: Kinematic characteristics of the knee joint are suitable for evaluation of the rehabilitation process. This can be realized by measuring the angle between Trochanter major, modeled rotational axis of the knee joint (Nietert 1998) and Malleoulus lateralis, for instance. A previous study has shown that the midstance Flexion-Extension-Motion of the knee joint is reduced during the rehabilitation of knee ligament injuries. A parameter for describing the reduced Flexion-Extension-Motion is the "Flexion-Extension-Deficiency" (FED, Schmalz et al. 1998). This parameter calculates the angle difference between stance phase flexion and stance phase extension with regard to the right-left-comparison. Negative values are defined as a deficiency of the injured leg. The reasons for the kinematic deficiencies can be explained by means of the external moments acting on the knee joint in the sagittal plane. During normal human gait there is a local flexion peak value in the first 50% of the stance phase. However, in the second 50% of the stance phase a local extension peak value can be measured. By using the right-left-comparison, both the flexion and the extension peak values show if there is a increase or decrease of muscular activities as a result of the disturbance of the knee joint function. The corresponding parameters are derived by Schmalz et al. (1998) and can be described as DM_{ZMIN} (flexion peak value) and DM_{ZMAX} (extension peak value).

RESULTS: Figure 2 shows the mean values for the FED of all patients compared with the controls. Both the patellar tendon autograft reconstruction group and the augmented repair group show a clear deficiency of about 3.5°. This deficiency is

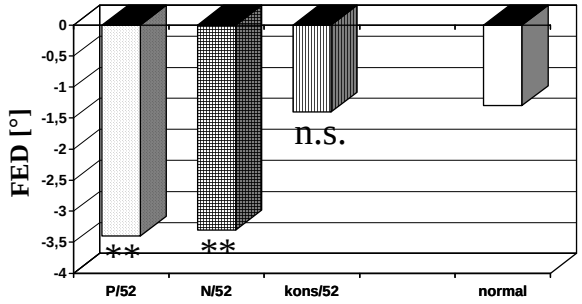

Fig. 2: Mean values of the Flexion-Extension-Deficit FED of all groups (P/52: patellar tendon autograft reconstruction; N/52: augmented repair; kons/52: non-surgical; normal: controls; negative values are deficiencies of the injured leg; **: difference with controls is significant (p<=0.01))

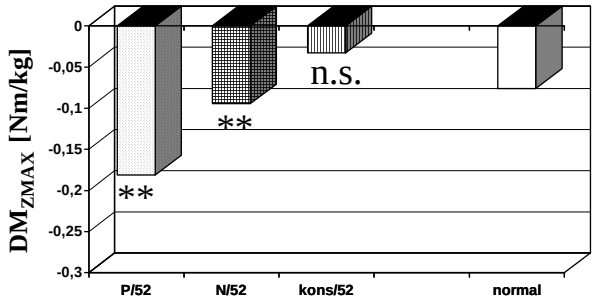

Fig. 3: Mean values of the deficiency of the extension moment peak value DM_{ZMAX} for all groups (sagittal component; all abbreviations corresponding to Figure 2; n.s.: difference with controls is not significant)

significant when compared with the controls. However, the non-surgical group cannot be distinguished from the controls one year after occurrence of the disruption. It can be concluded from the analysis of the knee joint moments that the deficiencies of the flexion peak values are only similar to the normal right-left-variations of normals. A significant increase in the extension peak values for both surgically treated groups is evident. Furthermore, the deficiencies of the patellar tendon autograft reconstructed knees are higher then those of the augmented repaired knees, as shown in Figure 3. There is no extension peak value deficiency for the non-surgical group.

DISCUSSION: Surgically treated groups show significant differences in important gait parameters compared with the normal gait. One year after treatment no significant difference could be found between the two surgically treated groups. The results of the non-surgically treated group indicate what an important influence surgery has on gait parameters. The deficiencies can probably be attributed to biomechanical problems like ligament graft positioning, fixation or pre-tensioning appearing during the operation. It seems to be very difficult to restore the exact

individual joint mechanics. Two problems need to be clarified by means of further investigations: firstly, if a reduction of the gait deficiencies can be expected after the first post-surgical year and secondly, if and how the gait deficiencies and long-term risks of osteoarthritis are interrelated.
On the other hand, in the case of a deficient ACL, additional neuromuscular controls partially substitute the joint stabilizing function of the ACL. Therefore deficiencies during normal gait are not measurable one year after the disruption. When discussing gait parameters it cannot be concluded that this compensation functions in extreme load situations. To protect the knee in these situations, e.g., in team sports like football or handball, restoring the mechanical joint stabilizing ACL function surgically seems vital.
The "quadriceps avoidance pattern" reported by Berchuck et al. (1990) could be measured only in individual cases, because the flexion moment shows no significant variations compared with normal gait. This is valid for all groups of patients. In most cases a reduced midstance Flexion-Extension-Motion can only be explained by reduced extension moments.

REFERENCES:

Berchuk, M., Andriacchi, T. P., Bach, B. R., Reider, B.(1990). Gait Adaptions by Patients Who Have a Deficient Anterior Cruciate Ligament. *J. Bone and Joint Surgery* **6**, 871-877.
Eckhardt, R., Scharf, H.-P., Puhl, W. (1994). Die Bedeutung der neuromuskulären Koordination für die sportliche Belastbarkeit des Kniegelenkes nach vorderen Kreuzbandverletzungen. *Sportverl. - Sportschäden* **8**, 16-24.
Friederich, N. F. (1993). Kniegelenkfunktion und Kreuzbänder. *Der Orthopäde* **6**, 334-342.
Nietert, M. (1977). Das Kniegelenk des Menschen als biomechanisches Problem. *Biomedizinische Technik* **22**, 13-21.
Timoney, J. M., Inman, W. S., Quesada, P. M., Sharkey, P. F., Barrack, R. L., Skinner, H. B., Alexander, A. H. (1993). Return of Normal Gait Patterns after Anterior Cruciate Ligament Reconstruction. *Am. J. of Sports Med*. **21**, 887-889.
Schmalz, T., Blumentritt, S., Wagner, R., Gokeler, A. (1998). Ganganalytische Verlaufsuntersuchung patellasehnenversorgter Rupturen des vorderen Kreuzbandes. *Physikalische Medizin* **1**, 1-8.