

Gait after knee arthroplasty for femoral tumor

Foot pressure patterns recorded in 20 patients

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We evaluated pressure distribution patterns under the feet during gait in 20 patients after resection of malignant bone tumor and endoprosthetic replacement of the distal femur. In all cases, a modular cementless, hinged prosthesis had been used. The examination was performed after 4 (1–6) years. Shortened contact phase, decreased peak pressure, and

reduced force-time integral during gait analysis were observed on the operated side. Peak pressure in the heel and the toe regions was decreased and the load (force-time integral) in the metatarsal heads and the big toe regions was reduced. There was a positive correlation between load under the foot and knee extension strength, measured isokinetically.

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Although many patients show good function after a wide resection of tumor and prosthetic replacement of the distal femur (Capanna et al. 1991), reports on quantitative gait analysis are rare (Suzuki et al. 1989, Otis et al. 1991). Complete symmetry in gait seems difficult to achieve in cases of extensive muscle resection of, especially, the quadriceps femoris. Some changes in gait pattern could be expected after muscle resection and it is unclear how this kind of treatment affects the roll-over process during gait. We evaluated gait after limb-salvaging operations by means of pedography and analyzed a possible correlation with knee extension strength.

Patients and methods

Patients

20 patients, who were treated with resection of the distal femur and reconstruction with a modular uncemented prosthesis (KMFTR) for a primary malignant bone tumor at the Department of Orthopedics, University of Vienna, formed the study group. Only those with excellent or good results according to Enneking (1987) and who could walk without any support were included; it was not the aim to show the overall success of the treatment. The average age at the operation was 23 (9–68) years.

In each of the patients (13 men and 7 women), a modular prosthesis had been implanted after wide

resection of the tumor (Kotz et al. 1986). Resection was extraarticular (with patellectomy) in 4 cases and intraarticular without patellectomy in 16. The patella was resurfaced, using a PCA prosthesis. An expandable type of prosthesis (Kotz et al. 1991) was used in 6 patients and the standard prosthesis in 14. The quadriceps muscle was partially resected according to the individual oncological situation. The hamstrings were maintained in all patients, except one who had a big posterior tumor. Both heads of the gastrocnemius were detached from the femur in all patients. Active and passive knee motion exercises were started 5 days after operation. Partial weight bearing was allowed after 6 weeks, and full weight bearing after 12 weeks.

At the time of the study, at a mean follow-up of 4 (1–6) years, there were no leg-length discrepancies in 12 patients, while 8 had some shortening; the average shortening was 0.6 (0–2.5) cm. All patients had normal range of motion in the hip, ankle and subtalar joints. There was no flexion contracture in the knee joints. The average flexion of the knee on the operated side was 99 (90–110) degrees.

Gait analysis

Pressure distribution analysis during gait was performed using the EMED[®] Gait Analysis System (Novel GmbH, München, Germany). Data were collected from the capacitive pressure distribution platform with 1344 sensors in an area of 200 × 340 mm. Patients were asked to walk at their own, self-selected

Table 1. Length of contact phase (ms), peak pressure (N/cm²), and force-time integral (%BWs) of total foot and in various regions under the foot. Mean SD

Side	Total foot	Heel	Midfoot	Metatarsal heads	Toes	Big toe
<i>Length of contact phase (ms)</i>						
Non-operated	714 82	402 86	501 74	618 77	507 108	490 127
Operated	676 69	413 97	472 80	583 72	466 135	468 122
P-value	0.0001	0.5	0.002	0.002	0.04	0.4
<i>Peak pressure (N/cm²)</i>						
Non-operated	59 25	41 21	13 11	39 19	22 8	48 25
Operated	48 18	34 11	11 5	37 21	15 6	33 15
P-value	0.02	0.03	0.2	0.5	0.002	0.02
<i>Force-time integral (%BWs)</i>						
Non-operated	58 7	16 4	5 3	29 5	2 1	6 3
Operated	51 4	17 8	4 3	24 5	2 1	4 2
P-value	0.0001	0.8	0.2	0.005	0.07	0.02

Statistical significance between both sides was assessed by paired *t*-test (n 20).

slow walking pace. The measurements were triggered by the first foot contact on the plate. On the average, 3 (2-4) recordings each for the operated and the non-operated leg were performed.

Using EMED-MULTIMASK[®] software, the recorded foot pressure image was divided by percentages of dimensions in the 5 regions: heel (H), midfoot (MF), metatarsal heads (MH), II-V toes (T), and big toe (BT).

The following parameters were obtained from the total foot and each zone described above: length of contact phase (ms), peak pressure (N/cm²), and force(N)-time integral (%BWs).

The average of all measurements for each foot was considered as a representative value for a single foot.

Muscle strength testing

Knee extension strength was measured isokinetically, using a Cybex 6000[®] dynamometer with a short lever arm and a dual shin pad (Lumex Inc., Ronkonkoma, NY, U.S.A.) while the patients were seated. The non-operated limb of the patients was tested first with 3 maximal knee extensions and flexions at 30°/s. Peak torque was obtained as the highest value from all repetitions and from all points in the range of motion. The operated leg was tested in the same manner.

Statistics

Data obtained from operated legs were compared with those from non-operated sides by the paired *t*-test. Correlation analysis was performed between pedographical parameters and knee extension strength, both presented as data for the operated side in percent of the non-operated side. Correlation was also determined

between leg length discrepancies in cm and each of the parameters of gait analysis.

Results (Table 1)

The average coefficient of variation within a single foot was 2 (0-5) percent for the length of contact phase, 7 (1-12) percent for peak pressure, and 2 (0-6) percent for the force-time integral.

The length of contact phase for the total foot and the regions of midfoot, metatarsal heads and II-V toes was shortened on the operated side, as compared to the non-operated side. In the heel region, on the contrary, the contact phase had a tendency to lengthen, although the difference was not significant.

Peak pressure was decreased for the total foot and in the regions of heel, II-V toes and big toe on the operated side. The force-time integral was also reduced on the operated side. There were differences between both sides for the total foot and in the regions of metatarsal heads and big toe. In the heel region there was no difference.

There was no correlation between leg length discrepancies and any of the pedographical parameters, except a positive correlation between the extent of shortening of the operated leg and peak pressure in the heel region on the non-operated side (r 0.7, P 0.002).

On the operated side, average knee extension strength (peak torque) was 28 (0-48) percent of the non-operated side. There was a moderate correlation between knee extension strength and force-time integral of total foot and the big toe region (Figures 1 and 2).

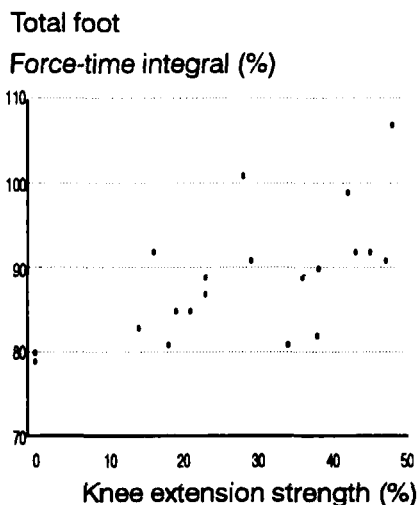


Figure 1. Correlation between knee extension strength and force-time integral of total foot on the operated side (r 0.6, P 0.004). Data are presented in relation to the non-operated side (percent).

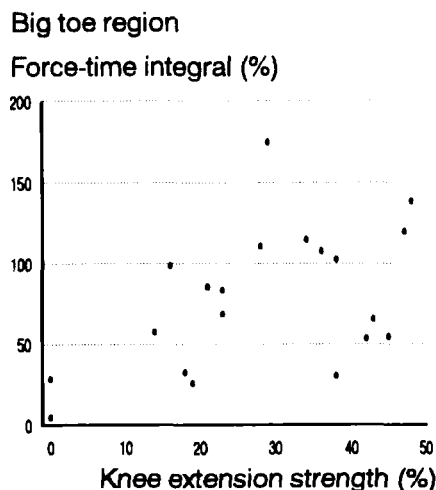


Figure 2. Correlation between knee extension strength and force-time integral in the big toe region on the operated side (r 0.5, P 0.03). Data are presented in relation to the non-operated side (percent).

Discussion

From the coefficient of variation within a single foot and a previous report about the reliability of the system (Hughes et al. 1991), we concluded that the average of all measurements for each foot was suitable for side-to-side comparison. Shortened contact phase, reduced peak pressure, and reduced force-time integral on the operated side revealed that the patients are, consciously or not, protecting their operated legs when walking.

In the heel region, contact phase did not shorten and force-time integral was not reduced, but peak pressure decreased, i.e., heels were supporting the load with a wider contact area and longer contact phase. This represents a cautiousness in the patients at the moment of heel-strike. Probably, the patients are walking with a modification of the early phase of the roll-over process so that more of the heel touches the ground simultaneously than in a normal gait. These results also agree with the tendency to increased peak pressure in the heel region in the non-operated, longer legs.

Reduced force-time integral in the metatarsal heads and big toe regions suggested a soft and cautious toe-off on the operated side. This may, in part, be due to gastrocnemius detachment from the femur. As a whole, a normal roll-over process was replaced by a rather simultaneous, soft-loading pattern.

The load under the foot is well represented by force-time integral (Hennig and Rosenbaum 1991). From the positive correlation between this value and

knee extension strength we conclude that quadriceps power is one of the important factors for symmetrical gait after limb-salvaging operations. A sufficient stability at the knee joint seems to be a prerequisite for normal loading of the foot. For this purpose, maximum retention of the muscle to an oncologically permissible extent at surgery and careful rehabilitation would be necessary.

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