The use of computer navigation for total knee arthroplasty – a follow up of rehabilitation by gait analysis

Doctoral Thesis

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Introduction

The operative technique and instrument system used for total knee arthroplasty is considered to be ideal. Nevertheless, there is a need for the continuous development of the prosthesis and well as improving the accuracy of implanting. Different computer navigation systems have been developed which will hopefully aid in the better positioning of the implanted components thus reducing the complaints caused by inexact implantation and optimistically will increase the duration time of the prosthesis.

Besides the development of the technique, the prosthesis, and the instrument system, patient demands are changing also. Patients want less pain, smaller incisions, quicker healing, which lead doctors to strive for these demands for their patients. The minimal invasive operative technique tries to satisfy these challenges. Instead of an 18-20 cm long skin incision continuing through the extensor apparatus, an 8-12 cm medial parapatellar skin incision and a mini midvastus approach is used. This spares the extensor apparatus, patella eversion is no longer necessary, thus decreasing soft tissue damage. Due to the smaller incision, the view of the joint compared to the traditional method is limited; the approach is a "mobile window" above the joint surface throughout the whole duration of the operation. The smaller surgical approach requires uniquely formed, smaller sized instrument systems.

The precise positioning of the components is crucial due to the smaller incision and similar to the traditional approach, this is where the computer navigation is used in the minimal invasive technique.

Many articles have compared the accuracy of component implantation in traditional and in minimal invasive approaches, but there is very little objective data concerning the two different methods' perioperative effects on the later rehabilitation. Do we actually profit from using the more time-consuming and expensive method? In our investigation, we compared the implantation accuracy of the traditional, the computer-navigated, and the computer navigated minimal invasive surgical techniques. Since the incision size probably directly effects the immediate postoperative period, we compared the conventional operative approach to the minimal invasive approach during the perioperative period. In order to determine the differences between the three surgical techniques, we examined the later rehabilitation period by observing the patients' gait parameters at the one-year follow up examination.

Objectives

The first goal of our research was the introduction of the computer navigation system for total knee prosthesis implantation at the Orthopedic Clinic at Semmelweis University and to determine how this influences implantation accuracy.

Our second objective was using the computer navigation system for minimal invasive total knee replacement, examining how the two new methods used together influence accuracy of implantation.

The third goal of our study was evaluating what effect the minimal invasive total knee replacement approach had on the first two weeks of rehabilitation.

The fourth aim was judging whether the Zebris ultrasound-based measuring system for gait analyses was eligible to record quantitative discrepancies in the gaits of healthy people of identical age groups and of patients with knee arthritis.

The fifth purpose of our study was examining whether the gait analysis device was eligible for the one year follow up examination of the above mentioned operations and whether the biometric results gained could be applied for the objective analysis of the rehabilitation.

The sixth objective – after the implementation of the fifth goal – was analyzing whether there is a recordable difference in the gait measurements during the rehabilitation of the three operations at the one year follow up examination.

Accordingly to the above mentioned objectives, the following hypotheses were conceived before beginning the research:

1. Most often, in literature, we find data proclaiming that computer navigation improves the implantation precision of the total knee prosthesis. However, the reported results show large discrepancies concerning the degree of accuracy. It was presumed that significant differences with regards to the accuracy of implantation would be observed at the Orthopedic Clinic of Semmelweis University for the benefit of the computer navigation.

2. It was assumed that if the navigation improves the implantation accuracy, then the reduction of incision size will not affect the advantages of the computer navigation adversely, the accuracy of implantation will not decrease significantly.
3. We found literature stating that total knee arthroplasty implanted by minimal invasive technique influences the postoperative first two weeks of rehabilitation positively. At the Orthopedic Clinic of Semmelweis University, we presumed that if we use identical postoperative protocols in both the traditional and in the minimal invasive techniques, a measurable difference will be observed in the rate of rehabilitation during the first two week period.
4. The ZEBRIS ultrasound gait analysis device has been previously successfully used for recording quantitative results in the gait parameters of young, healthy athletes and in cruciate ligament injured patients. It has also been utilized for the follow up of rehabilitation of operated anterior cruciate ligament ruptures. It was presumed that the system correctly measures the gait parameters of healthy, identical age group people and patients with knee arthritis as well as in the follow up of rehabilitation of patients treated with total knee arthroplasty.
5. Considering that the rate of rehabilitation is influenced mostly by the technique of the surgical approach, it was assumed that there would be no significant difference in the rate of rehabilitation at the one year follow-up of the non-navigated conventional approach versus the navigated conventional approach.
6. Patients who underwent minimal invasive surgery having less tissue damage and sparing the extensor apparatus would therefore have a quicker rate of rehabilitation than patients receiving one of the previous two surgical interventions. There will be significant differences in certain periods during the one year follow up in the three groups.

Material and Methods

During this research, the Orthopedic Clinic of Semmelweis University performed total knee arthroplasty by the conventional approach and with computer navigation in 70 cases. We performed 50 operations with minimal invasive technique using computer navigation. The 70 cases operated by the traditional approach at the same time period were considered the control group. We implanted the same type of total knee prosthesis in all of the operations – posterior cruciate ligament sparing Stryker Scorpio. Postoperatively, we applied a Johnes bandage on every patient's knee until the second postoperative day, when we removed both the bandage and the suction drain. All patients spent one day in the postoperative recovery room, then was moved to the orthopedic ward where they performed breathing exercises and muscle innervations physiotherapy. On the second day, after the removal of the Johnes bandage and the suction drain, knee movement and innervations exercises were started, the knee was placed on a continuous passive motion device. We observed how the range of motion changes in both groups and on which day knee flexion reached 90 degrees. The postoperative mobilization of both groups was done according to the same protocol for objective comparison.

According to the radiologic examination and in order to determine the stage of the knee joint arthritis, we used the Kellgren – Lawrence classification for selection of the patients for this study. All patients in this research had grade 4 arthritis of the knee.

We verified the preoperative axis and postoperatively the prosthesis components position by x-ray imaging in standard views. In all three groups, we performed full view lower extremity a-p and lateral direction x-rays.

It is expected that there is less tissue damage, a smaller skin incision, more sparing of the extensor apparatus and less blood loss when using the minimal invasive operative technique. We examined this implementation and technique in the early rehabilitation period. Presuming that the incidental differences were due to the type of surgical approach, we randomly chose 50 patients operated with the conventional approach (group I.) and compared their data to the 50 patients operated by the minimal invasive technique (group II).

We measured the incision length of each patient with their knees in an extended position. We measured the amount of intraoperative blood loss, compared each patients' preoperative hemoglobin (hgb) and hematocrit (htc) levels to the postoperative first day levels, and we recorded the amount of blood gathered in the suction drain upon removal on the second postoperative day.

Patients of all three operative groups filled out the HSS knee condition questionnaire preoperatively and at 3, 6, 9, and 12 months after the operation.

The ZEBRIS ultrasound based gait analysis device was used for the one year follow-up (18). Fifteen patients were chosen from each operative group. Patients were selected under the conditions that their knee arthritis was one-sided and they did not have any hip or spinal complaints. In all three groups, the arthritis affected the dominant extremity (conventional operative group: 13/15; navigated group: 12/15; navigated minimal invasive group 12/15). The fact that the selection criteria was so specifically determined and the time allotted for the gait analysis at the Budapest University of Technology and Economics was limited explains why we were only able to include 15 patients per group in our research. As a control group for gait analysis, we selected 21 people of the same age group, without any spinal-, hip-, or knee complaints per control group.

By fastening the device to the pelvic ring, the thigh and to the shin, ultrasound triplets formed on a coordinate system record on both lower extremities the medial malleolus, tuber calcanei, lateral malleolus, tuberositas tibiae, caput fibulae, lateral epiconylus of the femur, medial epicondylus of the femur, trochanter major and the I. spinal process of the sacral vertebrae.

During the research we measured the following time-distance parameters: gait length and width – the distance between the two medial malleoli.

We also recorded the degree of the knee and hip movements as well as the movements of the pelvis. The knee angle was the angle of the vector between the lateral malleolus – caput fibulae and lateral condylus of the femur – trochanter major femoris. The hip angle was determined as the angle between the vector of the lateral condylus of the femur – trochanter major femoris – spina iliaca anterior superior. The pelvic movements were defined as the pitching, rotation, and tilting in its own axis.

Since the gait analysis was done on a treadmill, the individuals walked for 6 minutes prior to the start of the measurements in order to get used to the treadmill's characteristics. The measurements were obtained at a speed of 2 km/h.

We examined individuals in the control group on one occasion, while the operated group was tested before the operation and 3-6-9-12 months postoperatively.
The data of the individuals involved in the examination can be seen in tables I and II.

	Number of patients women/men	Mean age	Preop a-p axis	Grade of arthritis
Control (n=70)	**70 51 women/19 men**	**68,5 (45-85) SD 6,9**	**2,9º varus 17º var.-28º valg. SD 5,53**	**4**
Navigated (n=70)	**70 47 women/23 men**	**69,4 (49-83) SD 6,8**	**4º varus 17º var.-26º valg. SD 5,9**	**4**
Navigated MIS (n=50)	**50 32 women/18 men**	**69 (45-80) SD 6,5**	**0,4 º varus 9º var.-15 º valg. SD 6,08**	**4**

Table I.
Data of patients who underwent surgery

	Number of patients Women/men	Mean age	Preop a-p axis	Grade of arthritis
Healthy (n=21	**21 (12 women/9 men)**	**52-84 SD 7,2**	**not measured**	**1**
Control (n=15)	**15 (7 women/8 men)**	**68,5 (55-81) SD 6,7**	**4,4º varus 15º var.-10º valg. SD 6,26**	**4**
Navigated (n=15)	**15 (9 women/6 men)**	**69,4 (60-79) SD 6,4**	**4,0º varus 12º var.-7º valg. SD 5,33**	**4**
Navigated MIS (n=15)	**15 (7 women/8 men)**	**67,2 (45-77) 6,5**	**4,06º varus 12º var.-9º valg. SD 5,38**	**4**

Table II.
Data of patients who underwent gait analysis

Results:

The average preoperative a-p axis in the control group was 2.9º varus, (17º varus-28º valgus) SD 5.53, in the navigated group was 4º varus (17º varus-26º valgus) SD 5.9, and in the navigated minimal invasive group was 0.4º varus (9º varus-15 º valgus) SD 6.08.

The measured results of the x-rays can be concluded as follows:

1. Analysis of x-rays after conventional operations (control group). The a-p positioning of the femoral component was 84.7º±2.4º (80º-93º), the average deviation from the optimal range was 1.2±0.5 degrees; in 74.2% of the cases, placement was optimal. The flexion-extension positioning of the femoral component was 2.3º±3.0º (0º-15º), the average deviation from the optimal range was 1.9±0.6 degrees, in 85.7% of the cases, positioning was optimal. The a-p positioning of the tibial component was 89º±2.7º (81º-96º), the average deviation from the optimal range was 1.1±0.5 degrees; in 70% of the cases, placement was optimal. The flexion-extension positioning of the tibial component was 4.6º±2.7º (-2º-12º), the average deviation from the optimal range was 1.6±0.9 degrees, in 65.7% of the cases, positioning was optimal. The postoperative axis was 6.4º±3.3º (-3º-18º), the average deviation from the optimal range was 1.7±0.9 degrees, in 62.8% of the cases, placement was optimal.
2. Analysis of x-rays after computer navigated operations. The a-p positioning of the femoral component was 83.9º±1.0º (82º-87º), the average deviation from the optimal range was 0.2º±0.0º degrees; in 97% of the cases, placement was optimal. The flexion-extension positioning of the femoral component was 0.8º±1.4º (-1º-8º), the average deviation from the optimal range was 0.5º±0.1º, in 95.7% of the cases, positioning was optimal. The a-p positioning of the tibial component was 89.4º±1.2º (86º-93º), the average deviation from the optimal range was 0.2±0.0 degrees; in 97% of the cases, placement was optimal. The flexion-extension positioning of the tibial component was 3.3º±1.5º (0º-6º), the average deviation from the optimal range was 0.2±0.0 degrees, in 95.7% of the cases, positioning was optimal. The postoperative axis was 6.9º±1.3º (3º-10º), the average deviation from the optimal range was 0.3±0.1 degrees; in 95.7% of the cases, placement was optimal.
3. Analysis of x-rays after computer navigated minimal invasive operations. The a-p positioning of the femoral component was 83.9º±1.3º (81º-86º), the average deviation from the optimal range was 0.2º±0.0º degrees; in 96% of the cases, placement was optimal. The flexion-extension positioning of the femoral component was 0.9º±1.1º (-2º-3º), the average deviation from the optimal range was 0.3º±0.1º, in 94% of the cases, positioning was optimal. The a-p positioning of the tibial component was 90.0º±1.2º (87º-93º), the

average deviation from the optimal range was 0.1±0.0 degrees; in 98% of the cases, placement was optimal. The flexion-extension positioning of the tibial component was 3.7º±1.6º (-3-7º), the average deviation from the optimal range was 0.6±0.2 degrees, in 88% of the cases, positioning was optimal. The postoperative axis was 6.7º±1.3º (4º-9º), the average deviation from the optimal range was 0.2±0.0 degrees; in 96% of the cases, placement was optimal.

The average length of the surgical incision in the minimal invasive group was 9.8 (8-12.5) cm, while the length of the incision in the conventional approach was 21.6 (18-23) cm.

Determining the precise amount of blood loss was more difficult. We calculated the difference between the preoperative and postoperative htc and hgb, and compared the intraoperative blood loss in the two groups. In order to estimate the following, we measured the amount of blood gathered in the suction drain on the second postoperative day.

The preoperative htc in the minimal invasive group was 41.3%, which decreased to 34.1% on the first postoperative day. Accordingly, there was a 7.2% decrease. The hgb level decreased an average of 29.8 g/l, from preoperative 135 g/l to 105.2 g/l on the postoperative first day.

The preoperative htc in the conventional approach group was 41.4%, which decreased to 32.5% on the first postoperative day. Accordingly, there was an 8.9% decrease. The hgb level decreased an average of 32.7 g/l, from preoperative 133.2 g/l to 100.5 g/l on the postoperative first day. Both the htc and the hgb level of decrease was significantly less ($p<0.01$) in group I.

The average intraoperative blood loss in the minimal invasive group was 241 ml, while in the conventional approach group was 236.1 ml. Until removal of the drain, we measured an average of 332.6 ml blood output after the minimal invasive surgery, and 513.6 ml after conventional approach surgery. We did not find a significant difference between the amount of blood loss intraoperatively in the two groups, however, the postoperative drain output of blood was significantly less after the minimal invasive approach surgery ($p<0.001$).

We monitored the rate of rehabilitation by observing the change in active knee flexion. Figure 1 shows the patients' improvement of movement in the first 12 postoperative days. It can be observed that the range of movement in the minimal invasive approach group exceeds that of the conventional approach group. Figure 2 demonstrates how many patients reach 90 degree flexion of the knee in correlation to time for both groups. It can be seen that patients operated by minimal invasive technique reach a 90 degree flexion of the knee sooner. According to both graphs, the improvement of knee movements in these patients is faster.

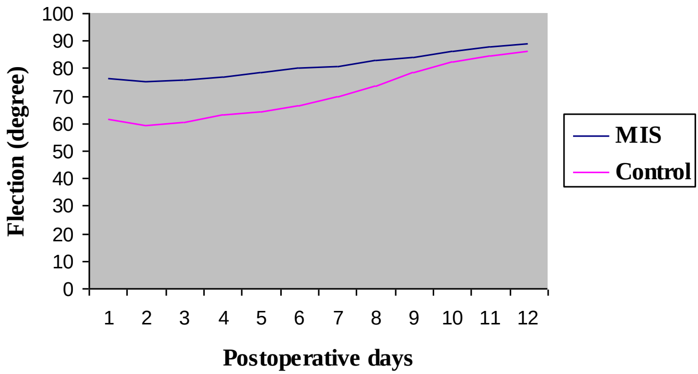

Figure 1.
Degree of flexion in correlation to time

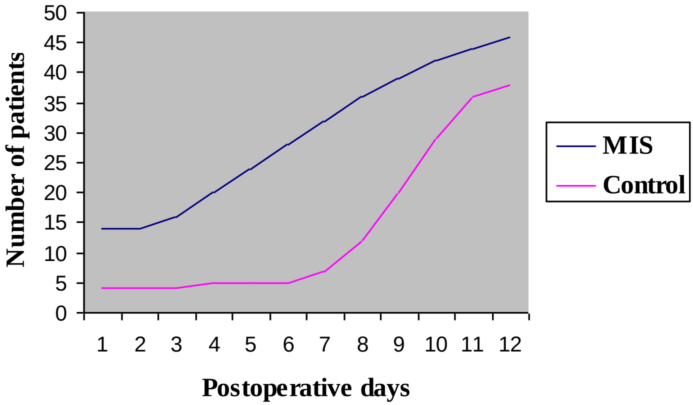

Figure 2.
Number of patients reaching 90 degree flexion in correlation to time

The results from the gait analysis are demonstrated in Tables III, IV, and V. In the conventional approach group (Group I.), the stride length of the patients was shorter than that of the healthy subjects (control group) prior to the operation and 3 and 6 months postoperatively. No significant improvement was observed at the 9 and 12 month follow-up. In the control group, the stride length was longer on their dominant side than on their non-dominant lower extremity. In group I, the stride length of the affected side was shorter for the first six months, thereafter the stride length of the operated extremity was longer than that of the non-operated side.

In the control group, the step width was greater on the non-dominant side. In group I, the affected side showed a larger value prior to the operation and during the first six month measuring. Afterwards, this value approached the value of the control group and no significant change was observed later. After the six month follow up, the step width of the operated extremity became less.

		Stride length (mm)		Step width (mm)	
Control		**A**	**B**	**A**	**B**
		875,6 ± 76.2	847,8 ± 78.9	20,7 ± 8.2	25,7 ± 8.3
Conventional		**A**	**B**	**A**	**B**
	Preop.	781.1 ± 66.4	775.3 ± 68.2	26.2 ± 5.8	30.1 ± 6.2
	Postop 3 months	820.3 ± 65.9	815.4 ± 66.7	25.3 ± 6.2	27.2 ± 5.9
	Postop 6 months	847.2 ± 69.8	855.2 ± 70.1	25.3 ± 6.4	23.1 ± 6.6
	Postop 9months	857.4 ± 73.6	868.6 ± 74.1	25.1 ± 6.7	23 ± 6.9
	Postop 12 months	855.6 ± 74.4	868.5 ± 75.6	25 ± 6.9	22 ± 6.8
Navigation		**A**	**B**	**A**	**B**
	Preop.	768.6 ± 60.2	760.4 ± 62.1	25,4 ± 6.1	30,1 ± 6.2
	Postop 3 months	820.5 ± 63.6	815.5 ± 65	25 ± 6.4	26,7 ± 6.6
	Postop 6 months	845.3 ± 68.1	858.3 ± 68.3	26,2 ± 6.9	24,3 ± 6.7
	Postop 9months	848.5 ± 69	861.4 ± 68.9	25,9 ± 6.9	23,3 ± 6.8
	Postop 12 months	850.4 ± 70.1	866.4 ± 70.3	25,5 ± 6.8	22,8 ± 6.9
Navigated MIS		**A**	**B**	**A**	**B**
	Preop.	790.1 ± 63.9	789.3 ± 66.2	26 ± 6.5	29,6 ± 6.7
	Postop 3 months	850.3 ± 66.8	860.2 ± 68.1	25,2 ± 6.6	25,1 ± 6.5
	Postop 6 months	856.2 ± 67.9	866.2 ± 67.8	25,1 ± 7	22,7 ± 6.9
	Postop 9months	858.4 ± 68.7	870.1 ± 69	25,3 ± 6.8	21,4 ± 7.1
	Postop 12 months	860.3 ± 70.2	872 ± 70.9	25,6 ± 6.7	21,2 ± 6.9

Table III. Changes in the stride length and the step width during the one year of rehabilitation, comparing the data with the parameters of the control group.
A – Dominant side of the subjects of control group, and healthy side of the patients of other groups. B – Non dominant side of the subjects of control group, and affected side of the patients of other groups.

		Hip angle (degree)		Knee angle (degree)	
Control		**A**	**B**	**A**	**B**
	ROM	32,3 ± 5,3	26,8 ± 4,8	51,4 ± 6,2	45,4 ± 5,6
	MIN	47,2±7,9	52,7±6,6	6,6±4,5	7,2±4,9
	MAX	79,5±6,5	79,5±7,2	58±6,9	52,6±6,7
Conventional		**A**	**B**	**A**	**B**
Preop.	ROM	22,4 ± 7,3	24,2 ±7,5	34,6 ± 6,3	29,9 ± 5,9
	MIN	51,9±5,8	54±6,1	9,4±5,2	13,4±3,8
	MAX	74,3±6,9	78,2±7,8	44±5,4	43,3±4,9
Postop. 3 months	ROM	26,9 ± 6,8	28,5 ± 7,2	37,5 ± 7,6	36,2 ± 6,3
	MIN	49,5±6,7	50,3±6,9	8,8±3,8	10,3±3,9
	MAX	76,4±8,1	78,8±7,1	46,3±4,7	46,5±5,3
Postop. 6 months	ROM	28,1 ± 6,9	30,2 ± 6,7	42,8 ± 6,6	43,2 ± 6,9
	MIN	49,3±5,3	49±5,8	8±3,9	8±4,2
	MAX	77,4±6,8	79,2±6,4	50,8±7,1	51,2±7,3
Postop. 9 months	ROM	28,2 ± 6,3	30,5 ± 6,9	43 ± 6,9	44,5 ± 6,2
	MIN	49,3±4,9	48,7±7,1	7,7±4,2	7,6±3,8
	MAX	77,5±6,7	79,2±7,6	50,7±6,3	52,1±7,2
Postop. 12 months	ROM	28,2 ±6,9	31,6 ± 7,2	43,25 ± 7,7	46,35 ± 7,1
	MIN	49,3±6,3	47,8±5,7	7,2±2,9	7,2±3,4
	MAX	77,5±6,9	79,4±7,8	50,45±6,7	53,5±7,3
Navigation		**A**	**B**	**A**	**B**
Preop.	ROM	24,5 ± 6,9	25,9 ± 6,6	35,3 ± 7,2	25,8 ± 6,8
	MIN	51,9±5,6	53±5,6	9,2±3,9	16,2±4,2
	MAX	76,4±7,2	78,9±7,4	44,5±6,8	42±7,1
Postop. 3 months	ROM	26,2 ± 7,2	26,7 ± 7,6	40,5 ± 7,8	36,4 ± 7,6
	MIN	51,3±6,1	52,5±5,9	8,4±4,1	11,4±3,4
	MAX	77,5±6,9	79,2±6,9	48,9±7,3	47,8±6,8
Postop. 6 months	ROM	27,1 ± 7,5	29,6 ± 7,2	42 ± 6,9	43,7 ± 7,3
	MIN	51,1±5,4	49,9±6,4	7,7±3,7	7,6±3,6
	MAX	78,2±7,3	79,5±6,9	49,7±7,9	51,3±7,1
Postop. 9 months	ROM	27,5 ± 6,8	31,9 ± 6,5	42,2 ± 7,4	45,6 ± 6,2
	MIN	51,1±5,2	47,7±6,3	7,8±4,1	7,2±3,9
	MAX	78,6±7,8	79,6±7,6	50±6,7	52,8±7,6
Postop. 12 months	ROM	27,6 ± 7,3	31,9 ± 6,8	42,4 ± 6,6	47 ± 6,8
	MIN	51,2±4,9	47,7±4,9	7,4±3,8	6,8±2,9
	MAX	78,8±7,7	79,6±6,7	49,8±7,3	53,8±7,3
Navigated MIS		**A**	**B**	**A**	**B**
Preop.	ROM	23,5 ± 6,7	27 ± 7,2	38,1 ± 7,1	28,7 ± 6,9
	MIN	51,5±4,9	51,1±6,1	8,9±4,2	13,6±4,8
	MAX	75±6,8	78,1±7,2	47±7,1	42,3±6,3
Postop. 3 months	ROM	24,3 ± 7,5	31 ± 6,3	39,5 ± 7,8	43,6 ± 7,3
	MIN	51,9±5,7	48,3±6,1	7,3±4,2	7,4±3,6
	MAX	76,2±7,2	79,3±6,8	46,8±7,3	51±7,1
Postop. 6 months	ROM	25,2 ± 6,8	31,8 ± 6.5	42,5 ± 6,3	45,7 ± 6,8
	MIN	51,9±5,8	47,5±5,5	7,3±3,9	7±3,2
	MAX	77,1±6,9	79,3±7,1	49,8±6,7	52,7±7,4
Postop. 9 months	ROM	26,5 ± 7,4	32 ± 6,9	43,3 ± 6,9	46,2 ± 7,1
	MIN	51,4±6,9	47,4±6,2	7,2±3,6	6,8±3,9
	MAX	77,9±7,4	79,4±7,4	50,5±7,8	53±7,3
Postop. 12 months	ROM	27,2 ± 7,1	32,5 ± 7,3	44,9 ± 7,2	48,3 ± 7,6
	MIN	51,1±6,1	47±4,9	7±4,2	6,7±3,8
	MAX	78,3±7,6	79,5±7,8	51,9±6,5	55±7,5

Table IV: Values of hip-, and knee angles and changes in ROM of the hip and knee joints during the one year of rehabilitation, comparing the data with the parameters of the control group. A – Dominant side of the subjects of control group, and healthy side of the patients of other groups. B – Non dominant side of the subjects of control group, and affected side of the patients of other groups.

		Flexion (°)	Rotation (°)	Tilting (°)
Control	ROM	5,7 ± 2,1	5,2 ± 3,1	3,8 ± 2,3
	MIN	10±2,8	-1,6±1,1	1,4±0,8
	MAX	15,7±2,9	3,6±1,4	5,2±2,6
Conventional				
Preop.	ROM	4,3 ± 1,7	8,66 ± 1,9	6,6 ± 1,9
	MIN	9,3±2,1	-2,9±1,2	1,2±0,6
	MAX	13,6±2,3	5,76±2,1	7,8±2,1
Postop. 3 months	ROM	4,7 ± 2,6	7,35 ± 2,8	6 ± 2,3
	MIN	9,5±1,9	-2,2±1,1	1,2±0,7
	MAX	14,2±2,8	5,15±1,4	7,2±
Postop. 6 months	ROM	4,7 ± 2,9	6,9 ± 3,1	5,5 ± 2,8
	MIN	9,7±2,6	-1,8±1,1	1,4±0,8
	MAX	14,4±3,1	5,1±1,4	6,9±
Postop. 9 months	ROM	3,7 ± 2,3	6,5 ± 2,6	4,73 ± 2,2
	MIN	8,8±2,7	-1,7±0,9	1,6±1,1
	MAX	12,5±2,1	4,8±2,1	6,33±2,1
Postop. 12 months	ROM	4,4 ± 2,7	6,4 ± 2,4	4,7 ± 1,9
	MIN	9,1±1,9	-1,6±1,3	1,6±1
	MAX	13,5±2,2	4,8±1,3	6,3±2,1
Navigation				
Preop.	ROM	4,9 ± 2,9	8,15 ± 2,8	8,3 ± 2,7
	MIN	9,6±1,9	-2,7±0,9	1,2±0,7
	MAX	14,5±3,2	5,45±1,3	9,5±2,2
Postop. 3 months	ROM	4,3 ± 1,6	7,8 ± 2,9	5,8 ± 2,4
	MIN	9,2±2,8	-2,5±1,1	1,2±0,7
	MAX	13,5±3,9	5,3±1,2	7±1,9
Postop. 6 months	ROM	4,1 ± 3,1	7 ± 2,5	4,6 ± 1,9
	MIN	8,9±2,4	-1,9±1,8	1,6±1,1
	MAX	13±2,7	5,1±2,1	6,2±2,4
Postop. 9 months	ROM	4,3 ± 2,7	6,7 ± 2,8	3,9 ± 2,3
	MIN	9,1±2,8	-1,7±1,2	1,6±1,2
	MAX	13,4±3,3	5±2,1	5,5±1,7
Postop. 12 months	ROM	4 ± 2,3	6,6 ± 2,6	4 ± 2,5
	MIN	8,8±2,9	-1,7±0,9	1,5±0,9
	MAX	12,8±3	4,9±1,2	5,5±1,8
Navigated MIS				
Preop.	ROM	5,1 ± 2,8	9,2 ± 3,1	6,7 ± 2,9
	MIN	9,7±1,7	-3±1,6	1,2±0,7
	MAX	14,8±2,2	6,2±1,7	7,9±2,3
Postop. 3 months	ROM	4,5 ± 2,3	6,9 ± 2,7	4,1 ± 2,5
	MIN	9,4±3,1	-2,1±1,2	1,4±0,8
	MAX	13,9±3,2	4,8±1,7	5,5±1,9
Postop. 6 months	ROM	3,6 ± 2,5	6,8 ± 2,4	3,9 ± 2,6
	MIN	8,9±1,6	-2±1,1	1,5±0,7
	MAX	12,5±1.6	4,8±1,3	5,4±1,6
Postop. 9 months	ROM	4,1 ± 1,9	6,8 ± 2,6	3,8 ± 1,8
	MIN	9,2±2,1	-1,7±0,9	1,5±0,9
	MAX	13,3±2,4	5,1±1,3	5,3±2,4
Postop. 12 months	ROM	3,6 ± 2,1	6,7 ± 2,8	3,6 ± 2,2
	MIN	8,8±2,3	-1,7±1,1	1,6±0,9
	MAX	12,4±2,9	5±1,4	5,2±2,1

Table V: Changes in ROM of the lumbar spine during the one year of rehabilitation, comparing the data with the parameters of the control group.

In the control group, we measured somewhat of a greater knee angle on the dominant side than that of the non-dominant extremity. In group I, we observed a slighter range of motion (ROM) than that of the control group, prior to the operation as well as in the first postoperative six months. However, we measured a steady, significant increase in the ROM in the first six months. After the first six months, we did not observe any more significant increase in the ROM, however the ROM of the operated extremity surpassed that of the non-operated side. In the control group, the range of motion of the hip was greater on the dominant lower extremity than that of the non-dominant extremity. In group I, we observed the same, but the difference between the two sides was less preoperatively and in the first six months after the operation. Afterwards, the hip's range of motion became similar in both groups.
In the analysis of the pelvic movements, we found very different values between the control group and group I. When observing pelvic flexion, rotation and tilting together, we can see a characteristic movement pattern. This movement pattern was entirely different in the two groups. In addition, pelvic movements in group I were greater than in the control group. After the first postoperative six months, the range of movements gradually decreased. No more decrease in range of motion was observed thereafter. The measured pelvic flexion, rotation and tilting remained distinct in the two groups during the one year follow up.
The results of the navigated operated group (group II) were similar to the results of group I. The stride length, step width, and trends in the changes of the range of motion were all in conformity. Similar to group I, the measured values of group II showed a significant increase in the ROM in the first postoperative six months, approaching the values of the control group.
The parameters of the minimal invasive computer navigated group (group III) showed an increase in the measured values, approaching the values of the control group until the postoperative third month. Thereafter, no further change was observed.

Conclusions

The objective of my research was to demonstrate the effects of the Stryker-Leibinger computer kinematic navigation on total knee arthroplasty, especially with regards to the accurate positioning of the prosthesis components. It was my intention to examine what influence the navigation and smaller incision had on each other with regards to implantation accuracy in the computer navigated, minimal invasive total knee arthroplasty. My next goal was assessing the influence the minimal invasive technique had on the first two postoperative weeks throughout the early rehabilitation period.
Since I also wanted to assess what influence the two new surgical techniques had on the postoperative events and rehabilitation compared to the conventional surgical approach, I tried to provide an objective, quantitative, and reproducible system to compare these parameters. For this assignment, I chose to use the ultrasound based ZEBRIS gait analysis device, which is very similar in terms to the operating principles of computer navigation.
I first examined whether the system was capable of producing comparable results in the examination of individuals belonging to the same age group. I then examined whether the system finds consequently measureable results in the gait parameters of healthy subjects of similar age and of patients with knee arthritis. To achieve this, I was determined to examine whether the device was capable of the follow up of the course of rehabilitation for patients who underwent total knee replacement. If so, my objective was to observe how the three different surgical approaches influence the course of the rehabilitation.

The following findings were established in the course of my research:

1. Literary data supports that computer navigation positively influences the accuracy of implantation. In addition, there is data – though much less – stating that the minimal invasive technique has a negative effect on component positioning, due to decreased visibility. However, I did not find any publications concerning the comparative evaluation of the three different surgical techniques within one orthopedic surgery center, using the same type of prosthesis and navigation system. During my research, I came to

determine that the accuracy of implantation did not decrease by using the computer navigated technique compared to the control group (conventional surgical approach), if the same navigation system was used for the minimal invasive surgical technique. Therefore I recommend that computer navigation should be used for the minimal invasive surgical technique, given the smaller incision and decreased orientation due to less visibility.

2. Because the essential of precise implantation is to achieve optimal biomechanical conditions in the knee joint, more accurate implantation or navigation has no direct effect on the postoperative period. The less tissue damage caused by the minimal invasive surgical technique may influence the immediate postoperative period. By examining the degree of knee flexion in the patients after the operation and in the following two postoperative weeks, I found that the patients' degree of knee flexion is already greater than those in the conventional surgical approach group, and these patients also reach a 90 degree knee flexion earlier. If we accept the intraoperative and postoperative blood loss as an indicator of tissue damage, then it is important to estimate its amount. It is very difficult to acquire an exact value – if even possible – therefore literature uses htc or hgb, and extremity circumference measurements to estimate the amount of blood loss. Due to the fact that neither measurement is exact, nor is one single value relevant, I used both htc and hgb, as well as the drain output of blood to assess the amount of blood loss. As a result, I found that both the htc and hgb values in the minimal invasive surgical group decreased significantly less that that of the control group. The drain output of blood was also significantly less in the minimal invasive surgical approach group. Therefore, by considering all three values, it can be more certainly stated that the minimal invasive technique leads to less postoperative blood loss.
3. By using the ZEBRIS gait analysis device, we examined how we can create conditions where the gait parameters of individuals can be compared to others and to their own previous values at any given time. I found that stride velocity can influence these parameters. However, by examining different walking speeds, I found that if the gait analysis is examined at identical speeds between 2-5 kilometers/hour, then the ZEBRIS device can provide reproducible, successive, and reliable results.

4. Coming to these conclusions, I examined the one year rehabilitation of the three different surgical approach groups using the device. I observed similar quantitative, qualitative and dynamic changes in time in subjects of the same group, which lead me to conclude that the device was capable of objectively analyzing the rehabilitation of patients' who underwent total knee replacement surgery.

5. Based on these observations, I examined what effect the different operations had on rehabilitation in correlation with gait parameters. I then came to the following conclusions:
   a. During the course of the one year follow up, gait parameters gradually approached the parameters of the healthy control group.
   b. In cases where the affected side was the patient's dominant lower extremity, then the other healthy extremity will play the role as the dominant side. However, as time passed, the operated extremity once again showed gait parameter values characteristic of the dominant side.
   c. The gait parameters of the conventional and computer navigated groups improved significantly during the course of the first six months, approaching the parameters of the control group, while the gait parameters of the computer navigated minimal invasive group showed significant improvement in the first three months. Therefore, I came to the conclusion that there is a difference in the rehabilitation rate between the three groups even in the first three months after the operation, i.e. the rehabilitation of the minimal invasive group is already more advanced in the first three postoperative months.
   d. Another proof of this is that while in the minimal invasive group it took three months for the operated dominant extremity to once again play its role as the prevailing extremity, in the other two groups this was observed only after six months after the operation.
6. By combining the gait analysis with EMG examination, I came to the following conclusions: The medial and lateral vastus, and rectus femoris muscles showed a decreased activation time in knee arthritis, compensated by the gastrocnemius, gluteus medius, biceps femoris muscles' increased activation time. In the minimal

invasive surgery group, the activation times normalized by the third postoperative month. In the other two groups, this was seen only from the sixth month after the operation. This demonstrates that there is a difference in the function of the extensor apparatus even three months postoperatively between the three operations, in favor of the minimal invasive category.

List of personal publications

1. First author publications in the topic of the dissertation:

Bejek Z. Paroczai R. Illyes A. Kiss RM. The influence of walking speed on gait parameters in healthy people and in patients with osteoarthritis. Knee Surgery, Sports Traumatology, Arthroscopy. 2006;14(7):612-22.

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2. Co-author publications in the topic of the dissertation:

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4. Book chapters

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