



Gait analysis of patients following totalcondylar knee arthroplasty

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rezime The aim of this study was to evaluate total knee arthroplasty success, throw gait analysis of patients who were underwent a surgery according to objective indicators.

Material and methods: Fourteen patients were participated in our study who suffered from a certain type of gonarthrosis. Data were gathered (collected) using a commercial OptiTrack system for motion recording using six infrared cameras. Markers were placed on patients' lower extremities, on previously determined anatomical regions. After recording the data were processed using computing environment MATLAB.

Results: Observing our lab results we noticed a significant reduction in range of motion (ROM) of arthritic knees in relation to the healthy knees. ROM reduction is primarily related to flexion and extension, as well as to medial and lateral translation. Following the TKA, ROM increases, and these values get close to the values that were measured in a healthy knee. The results were presented using graphs for a healthy, damaged and operated knee, and values of corresponding parameters were given using tables.

Conclusion: Using our results we showed that there is a big difference in the movement pattern of patients with gonarthrosis before and after the TKA and that that difference can be determined successfully and quickly using Optitrack system.

Key words: Gonarthrosis, Gait analysis, Flexion/extension of the knee, Medial/lateral translation

INTRODUCTION

Gonarthrosis is a degenerative illness of the knee joint. It is characterized by progressive degradation of knee joint cartilage. Knee arthrosis causes pain, leads to physical disability and the loss in quality of life¹.

Total knee arthroplasty is a treatment of choice for the terminal stadium of knee arthrosis. The number of implanted knee endoprosthesis increases exponentially around the world, and it includes younger population^{2,3}. Total knee arthroplasty is a reliable method of treating patients with this illness in order to reduce pain and increase knee joint function⁴.

Degenerative changes in the knee joint lead to abnormality of the gait pattern. Due to aforementioned changes there is a reduction in knee joint movement, which can be detected using biomechanical gait analysis. Recording and data processing are done in specialized laboratories for gait analysis. To evaluate the success of knee osteoarthritis using arthroplasty, radiography (long standing X-rays) that indicates the position of the implant, and subjective clinical diagnostic tests are currently used. In everyday clinical practice does not exist functional tests for assessment of the surgery success and improvement of the patients gait. The aim of this study is to determine success of the surgical procedure using gait analysis of patients who underwent the surgery, according to objective indicators in order to restore range of motion of the knee and gait normalization.

MATERIALS AND METHODS

Fourteen patients were included in the examination, whose average age was $68,79 \pm 5,98$ years, and they had an average weight of $81,5 \pm 16,18$ kg, and average height of $167,86 \pm 8,51$ cm. All patients suffered from certain type of gonarthrosis (GA). GA was diagnosed according to clinical examination, and it was confirmed according to a radiographic image. Patients with osteoarthritis gradus 3 and 4 (Kellgren-Lawrence classification) were included in the study⁵. Patient testing and surgical procedures were conducted at Clinical Center Kragujevac according to rules of the Helsinki declaration and good clinical practice with approval of the local Ethical Committee.

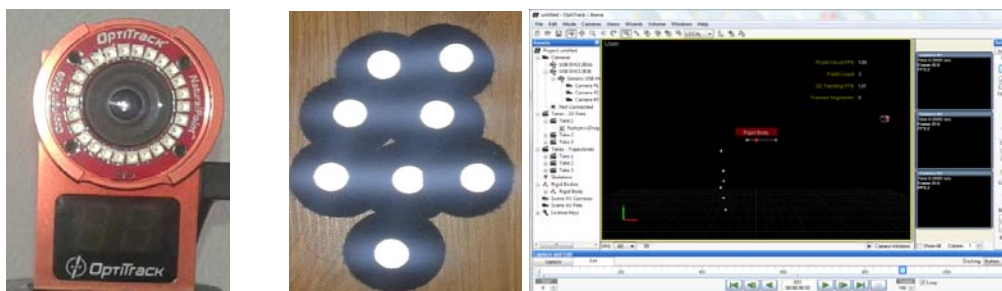


FIGURE 1. OPTITRACK SYSTEM: A) OPTICAL CAMERA FLEX 3, B) FLUORESCENT MARKERS, AND C) SOFTWARE ARENA

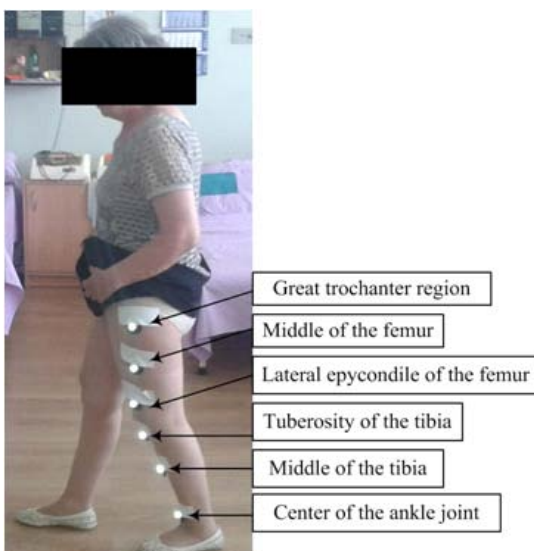


FIGURE 2. MARKER POSITION

In order to better understand the illness and motion limitations, gait analysis was conducted using OptiTrack system.

OPTITRACK SYSTEM

Kinematic data were collected using commercial 3D OptiTrack system for motion analysis. The system consists of six infrared cameras (Flex 3) that recorded the motion of fluorescent markers (10 mm in diameter) and of monitoring software ARENA (Fig. 1). Markers were placed on patients' lower extremities, on precisely determined anatomical regions: on great trochanter region, middle of the femur, lateral epycondyle of the femur, tuberosity of the tibia, middle of tibia and on the center of the ankle joint (Fig. 2). The markers were fastened using sticking plasters that were directly applied to the skin.

According to the protocol, the patients had a task to freely move on a horizontal path in the length of 5m (Fig. 3). The task was performed twice. Firstly the motions were recorded on the damaged, and then on the healthy leg. After recording and data processing using the computing environment MATLAB, as a result, a series of 3D coordinates from marker positions is obtained, in function of time for each placed marker. The markers are purposefully placed on the lower extremities to mark the be-



FIGURE 3. EXPERIMENTAL SETTING

ginning and the end of a vector. Using the position of marker coordinates, it is possible to determine a change in flexion degree, and a change in medial lateral translation. Knee joint flexion is calculated according to the angle between two vectors (Fig. 4):

$$\cos \theta = \frac{V_1 \cdot V_2}{|V_1| \cdot |V_2|}$$

Where are:

V_1, V_2 -Scalar sum of two vectors,

-Vector intensity between points $A(x_1, y_1)$ and $B(x_2, y_2)$, and

-Vector intensity between points $C(x_3, y_3)$ and $D(x_4, y_4)$.

Determination of medial lateral (ML) translation (dCLM) is done using successive division of marker position coordinates (placed on tuberosity of tibia) along medial lateral direction:

$$d_{CLM} = (CLM)_{i+1} - (CLM)_i, mm$$

RESULTS

Table 1 shows average values of changes in knee flexion and medial lateral translation for the phases Loading response, Mid stance, Terminal stance and Pre swing on the knee with GA, on contralateral healthy knee, and after operation.

Fig. 5a and 5b show flexion and ML translation on OA knee. The curve on the diagram 5a indicates that the knee is slightly flexed during the complete standing phase, and that the angle of leg flexion remains unchanged. Before

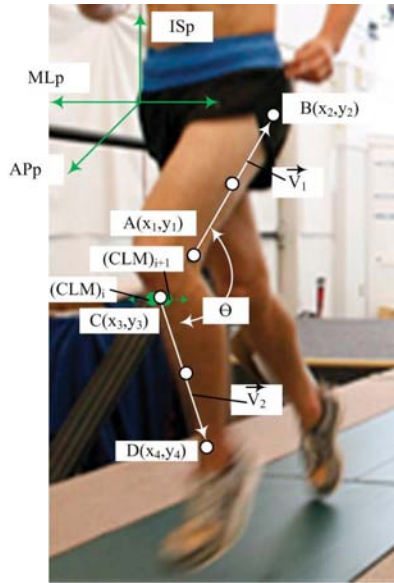


FIGURE 4.
VECTOR POSITION ON THE LEG

Legend: - vectors; $A(x_1, y_1)$ – beginning of vector; $B(x_2, y_2)$ – end of vector; $C(x_3, y_3)$ – beginning of vector; $D(x_4, y_4)$ – end of vector; θ – degrees of knee flexion; $(CLM)_i, mm$ – position of C point in i -th moment; $(CLM)_{i+1}, mm$ – position of C point in $i+1$ -th moment; MLp – medial lateral direction; APp – anterior posterior direction; ISp – inferior superior direction

the Swing phase, knee flexes slightly. Diagram on the picture 5b shows ML movement which is close to zero.

Fig.5c and 5d show flexion and ML translation on the contralateral healthy knee. Diagram is characterized by two amplitude rises. The first rise appears in Loading response phase, and the second one during Swing phase. There is a slight ML translation during the entire gait cycle on the healthy knee.

Fig.5e and 5f show flexion and ML translation on the knee with prosthesis. Flexion diagram has a shape of the diagram of healthy contralateral leg, and two amplitude rises appear in standing and Swing phases. ML translation appears during the entire gait cycle.

DISCUSSION

Many studies deal with gait analysis of all joints on the lower extremities using modern optical 3D devices for motion recording⁶⁻¹¹. Thus G L. Hatfield et al. used OptiTrack system 3020 (Northern Digital, Inc, Waterloo, Ontario, Canada) to analyze gait parameters with knee osteoarthritis¹². Also A. Bonnefoy-Mazure et al. used Vicon system (VICON Peak, Oxford, UK). They conducted gait analysis using twelve infrared cameras. Fluorescent markers were used in our study, and positioned on the patients' body¹³.

Knee osteoarthritis leads to the reduction of motion and deficiencies of gait pattern. Our findings showed a very significant motion reduction on deficient knees in relation to healthy knees. Motion reduction in our research is primarily concerned with flexion and extension, and secondly medial and lateral translation (Tabl. 1, Fig. 5a and 5b)^{14,15}.

TABLE 1

AVERAGE VALUES OF FLEXION DEGREE CHANGE AND ML TRANSLATION FOR PHASES LOADING RESPONSE, MID STANCE, TERMINAL STANCE AND SWING ON THE KNEE WITH GA, ON CONTRALATERAL HEALTHY KNEE, AND AFTER OPERATION

Knee	Phase	Flexion, %	ML translation, mm
OA	Loading response	4.03±0.05	0.07±0.17
	Mid stance	4.35±0.17	-0.02±0.14
	Terminal stance	4.62±0.14	0.11±0.09
	Swing	8.11±3.68	0±0.17
Healthy	Loading response	12.62±1.07	0.23±0.17
	Mid stance	18.63±2.59	0.14±0.51
	Terminal stance	17.29±1.46	0.43±0.38
	Swing	39.65±12.55	0±0.31
Prosthesis	Loading response	24.16±0.63	0.14±0.53
	Mid stance	25.53±1.38	0.25±0.27
	Terminal stance	27.51±0.87	0.75±0.17
	Swing	36.53±3.81	0.08±0.84

Following the knee prosthesis implantation, range of motion increases regarding knee flexion/extension and medial/lateral translation, which is similar with the healthy knee (Fig. 5c, 5d, 5e, 5f). Two amplitudes are clearly present in standing phase during knee extension, and in the swing phase with knee flexion. Also increased medial/lateral translation for the entire gait cycle is visible with the treated knee, and these values approach the values that were measured on a healthy knee during previous researches^{12,16,17}.

Knee endoprosthesis implantation affects gait pattern what confirmed Aeon Lee et al. They compared the gait analysis of young women after the implantation of knee endoprosthesis with gait analysis of healthy women¹⁸.

CONCLUSION

With our results we have shown that there is a clear difference between a gait pattern in patients with gonarthrosis before and after endoprosthesis implantation, and that that difference can be successfully and quickly determined using Optitrack system. Further examination are directed to comparative analysis of knee motion after arthroplasty depending on the type of endoprosthesis.

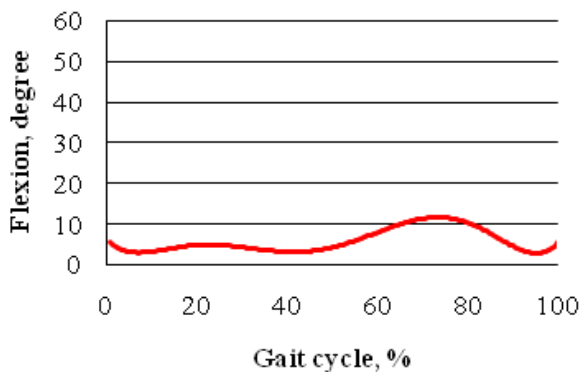


FIGURE 5A
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
FOR THE KNEE WITH GA,

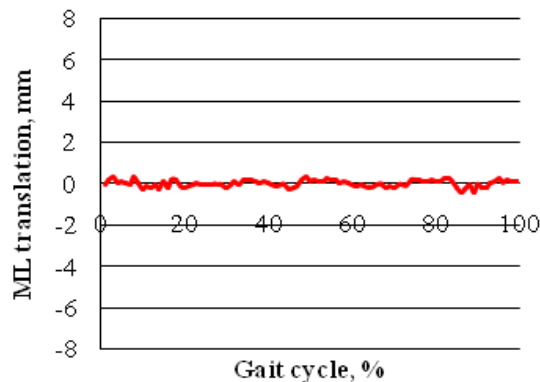


FIGURE 5.B
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
FOR THE KNEE WITH GA,

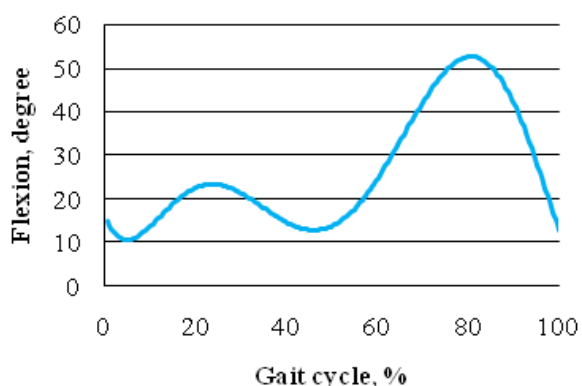


FIGURE 5C.
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
CONTRALATERAL HEALTHY KNEE ,

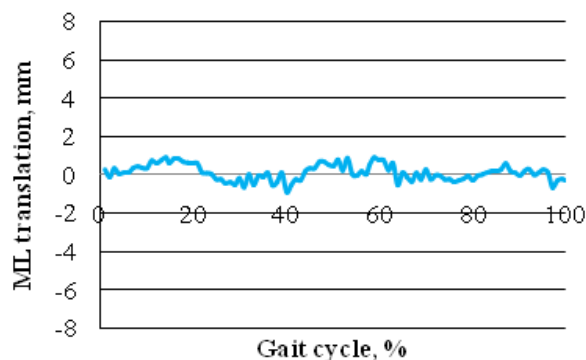


FIGURE 5D.
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
CONTRALATERAL HEALTHY KNEE

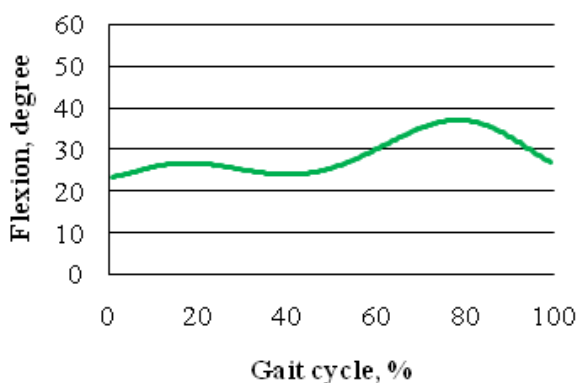


FIGURE 5E.
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
AFTER OPERATION

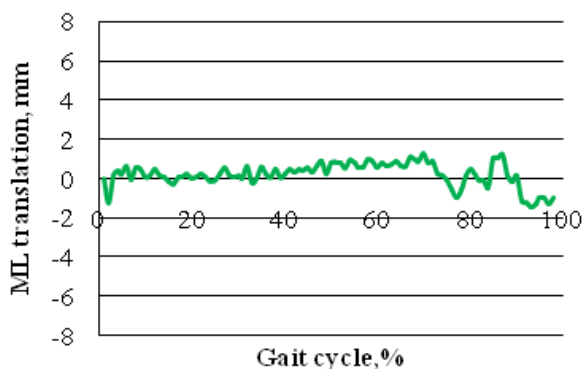


FIGURE 5F.
CHANGE IN FLEXION DEGREE AND ML TRANSLATION:
AFTER OPERATION

SUMMARY

ANALIZA HODA PACIJENATA NAKON UGRADNJE TOTALNE ENDOPROTEZE KOLENA

Cilj studije je da na osnovu objektivnih pokazatelja definišemo uspešnost totalne artroplastike kolena, kroz analizu hoda operisanih bolesnika.

Materijal i metode: U ispitivanju je učestvovalo 14 pacijenata koji su imali neki oblik gonartroze. Podaci su zabeleženi korišćenjem komercijalnog OptiTrack sistema za snimanje kretanja sa šest infracrvenih kamera. Markerji su postavljani na donje ekstremitete pacijenata, i to u tačno određenim anatomskim regionima. Nakon izvršenog snimanja, podaci su obrađeni korišćenjem programskog okruženja MATLAB.

Rezultati: Merenjem smo dobili veoma izraženu redukciju u pokretima kod obolelih kolena u odnosu na zdrava. Redukcija pokreta se prvenstveno odnosi na fleksiju i ekstenziju, kao i na medijalnu i lateralnu translaciju. Nakon ugradnje proteze kolena, obim pokreta se povećava i vrednosti se približavaju vrednostima koje su izmerene na zdravom kolenu. Rezultati su prezentovani grafičima za zdravo, bolesno i operisano koleno, a vrednosti odgovarajućih parametara su date tabelarno.

Zaključak: Našim rezultatima smo pokazali da postoji jasna razlika u obrascu kretanja kod pacijenata sa gonartrozom pre i posle ugradnje endoproteze i da se ta razlika uspešno i brzo može utvrditi uz pomoć OptiTrack sistema.

Ključne reči: Gonarthrosis, Gait analysis, Flexion/extension of the knee, Medial/lateral translation

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