

The Influence of Total Knee Arthroplasty on Postural Control

G. Stan¹, H. Orban¹, C. Orban², D. Petcu³, P. Gheorghe⁴

¹Elias University Hospital, ²Fundeni Clinical Institute, ³National Research and Development Institute for Textiles and Leather-Leather and Footwear Research Institute, ⁴Pantelimon University Hospital
Bucharest, Romania

Rezumat

Influența intervenției de artroplastie totală de genunchi asupra echilibrului

Introducere: Scopul acestui studiu este evaluarea efectelor induse de artroplastia totală de genunchi asupra echilibrului. **Material și metodă:** Măsurătorile au fost efectuate cu ajutorul platformei de forță "AMTI AccuGait". Subiecții au efectuat câte 3 probe de echilibru în stațiune bipodală. Au fost măsurate deplasarea mediolaterală și anteroposterioară, viteza de deplasare și Elipsa 95.

Rezultate: Deplasarea mediolaterală a crescut cu 3,4% post-operator, iar cea anteroposterioară, cu 23,2%. Viteza medie de deplasare a crescut cu 16,8%, iar Elipsa 95 cu 33,7%.

Discuții: Cu excepția deplasării mediolaterale, toți ceilalți parametri măsurați au înregistrat creșteri semnificative statistic ($p < 0,05$), în perioada postoperatorie față de cea preoperatorie.

Concluzii: Studiul demonstrează scăderea echilibrului în perioada imediat următoare artroplastiei totale de genunchi. Aceasta este o perioadă sensibilă în care pacienții sunt predispuși riscului de traumatisme prin cădere.

Cuvinte cheie: artroplastie totală de genunchi, echilibru, propriocepție

Abstract

Introduction: The aim of this study is to assess the changes induced by the unilateral total knee arthroplasty procedure in human postural control.

Materials and methods: The measurements were performed using the "AMTI AccuGait" force plate. Subjects completed three consecutive double-limb standing balance trials. The mediolateral and anteroposterior displacements were derived from the force and moment profiles measured by the force platform. The path length per unit time (average velocity) and Elipse 95 (collect 95% of data) were also assessed.

Results: Mediolateral displacement increase of 3.4% was observed postoperatively. Postoperative anterolateral displacement increase of 23.2% was recorded. The average velocity also rose by 16.8% postoperatively. The Elipse 95 grew by 33.7% postoperatively.

Discussion: Excepting mediolateral displacement, all the other studied parameters showed significantly ($p < 0.05$) higher values in the postoperative period compared with the preoperative one, in both open and closed eye trials.

Conclusions: The study results demonstrate that balance control is weaker shortly after unilateral knee arthroplasty, than in the preoperative period. Although proprioception is altered in osteoarthritic knees, the TKA procedure may additionally affect proprioceptors. The TKA causes additional instability in the days after the procedure, therefore the risk of falling injuries is higher in this period.

Key words: knee arthroplasty, balance control, proprioception

Corresponding author:

Gabriel Stan, MD
1 Decembrie 1918 Blvd, no 35, bl L14, sc 7
ap. 268, sector 3, postal code: 032456
Bucharest, Romania
E-mail: gabibus2000@yahoo.com

Introduction

The aim of this study is to assess the changes induced by the unilateral total knee arthroplasty procedure in human postural control.

Knee arthroplasty (TKA) is a commonly-used solution to address knee arthritis. The knee joint is frequently affected by weight bearing, and knee arthritis is a risk factor for fall injuries. Knee arthritis can be a particularly serious problem for elderly patients, where osteoporosis is often associated. Considering the current population aging tendency, and the deterioration of balance control ability with age, knee arthritis is a pathology requiring special attention.

Although many studies have measured the success of knee arthroplasty in terms of survival, another important aspect of TKA is its functional outcome; that is, postoperatively, patients should be free of pain and able to perform daily activities such as standing, walking and stair-climbing.

Balance control is related to the vestibular system, sight, proprioception, muscular strength, and cognition (1). Yet, when knee osteoarthritis progresses, changes occur in the tissues within the articular cavity, in ligaments, tendons, and periarticular tissues, including the muscles (2). Furthermore, patients with knee arthritis have a disability in their proprioception compared to similar age controls. Histological tests have shown that the number of mechanical sensory receptors around the ligaments of arthritis knee joints is reduced (3,4).

A number of tests can be performed to assess balance control, such as the timed up and go test, the 10 meter walking test, the functional reach test and the Berg balance scale (5,6). The shortcomings of these tests, however, are that they may introduce subjective elements and they cannot assess all the various aspects of balance control. On the other hand, static or dynamic posturography can calculate balance control quantitatively by postural sway, including different postures which induce changes in sight and the somatic sense (7).

Thus, Hassan et al. have concluded that pain and muscle strength affect postural sway, as they found that the quadriceps femoris muscle strength and proprioception are decreased and postural sway is increased in the knee OA group compared to sex- and age-matched controls (1). Moreover, Hasegawa has identified a correlation between the worsening of radiologic test results and an increase in the knee OA patients' postural sway (8). Finally, Kim has observed that moderate to severe OA patients had diminished balance control compared to mild OA patients (7). Consequently, we have been able to deduce that increased pain and decreased muscle strength and proprioception contribute to postural instability.

In this study, the ability to control balance is analysed quantitatively by calculating the difference in weight bearing distribution between the preoperative and postoperative periods, by using a force plate.

Materials and Methods

The study group consisted of ten patients, i.e. seven females

and three males. All patients suffered from single knee arthritis and had undergone unilateral knee arthroplasty with the same type of posterior cruciate ligament substituting prosthesis. In all cases, the implants were inserted with cement. All surgeries were performed by the same main surgeon, using the under vast muscle approach. All patients started active motion of the prosthetic knee the day after the surgery. The mean age at the time of the TKA was 63.5. The mean height and weight were 1.73 m and 74 kg, respectively.

The following including criteria were used:

- Albach 3 radiological arthritis;
- Preoperative varus knee deformity < 15°;
- Unaffected contralateral knee.

The excluding criteria comprised:

- neurological disorders;
- significant heart disorders;
- previous surgical limb procedures;
- medication that might affect sight or balance control;
- known diseases probably influencing proprioception, such as neuromuscular or rheumatic diseases or diabetes mellitus.

The measurements were performed using the "AMTI AccuGait" force plate. The force platform was 46 * 51 cm in size and was mounted flush with the lab floor. During each test trial, Biomechanics Data-Acquisition and Analysis Software (AMTI version 3.1) was used to obtain 30 s of force platform output at a sampling rate of 5 Hz.

Subjects completed three consecutive double-limb standing balance trials, under two different testing situations: 1) standing on the firm and stable platform with eyes open, 2) standing on the firm and stable platform with eyes closed. Rest periods of 30 to 60 seconds were provided between trials, and at least one minute's rest was provided between each test situation. During the standing tests, subjects stood on their limbs centred on the force platform and with their knee in full extension. The standing position was "closed base", that is, the heels and toes were in contact.

Data collection was initiated with a computer keystroke, when the mentioned position had been attained and subjects stated that they were ready. Subjects were trained to look straight ahead at a cross marked approximately at eye level on a blackboard 5 m away, when performing open eye trials. For the closed eye trials, subjects looked at the same cross before firmly closing their eyes (9). The position of each subject's feet was temporarily marked on the floor in order to perform three standing trials.

If balance was not maintained and the subjects could not maintain double-limb stance for the full 30 seconds, or if they required a step, the trial was not recorded and was repeated.

Subjects were informed that the purpose of each balance test was to examine how still they could stand during the various testing situations. They were asked to concentrate on standing as still as possible for the 30 seconds and to correct their position as quickly as possible if a disturbance occurred (9,10). The trials were performed for each patient two days before surgery and 7 days after knee replacement, when

Table 1. Study results

Type of analysis - open eye, OE -	Before surgery	Romberg OE / CE	After surgery	Romberg OE / CE	%, Pre / Post -Mean-
	Mean value		Mean value		
Medio-lateral (cm)	1.97	-	2.04	-	3.4
Antero-posterior (cm)	1.69	-	2.20	-	23.2
Velocity (cm/s)	1.39	-	1.67	-	16.8
Elipse 95 (cm ²)	2.22	-	3.35	-	33.7
Type of analysis - closed eye, CE -	Before surgery	Romberg OE / CE	After surgery	Romberg OE / CE	%
	Mean value		Mean value		
Medio-lateral (cm)	2.98	1.51	3.14	1.53	5.1
Antero-posterior (cm)	2.35	1.39	3.09	1.4	23.9
Velocity (cm/s)	1.74	1.25	2.15	1.28	19.1
Elipse 95 (cm ²)	3.82	1.72	5.58	1.66	31.5

patients felt no more pain.

The mediolateral and anteroposterior displacements were derived from the force and moment profiles measured by the force platform. The path length per unit time (average

velocity) and Elipse 95 (collect 95% of data) were also assessed.

According to the coordinate system, the subjects were positioned to look forward on the positive “y” axis. The anterior displacement was considered “y” positive, and

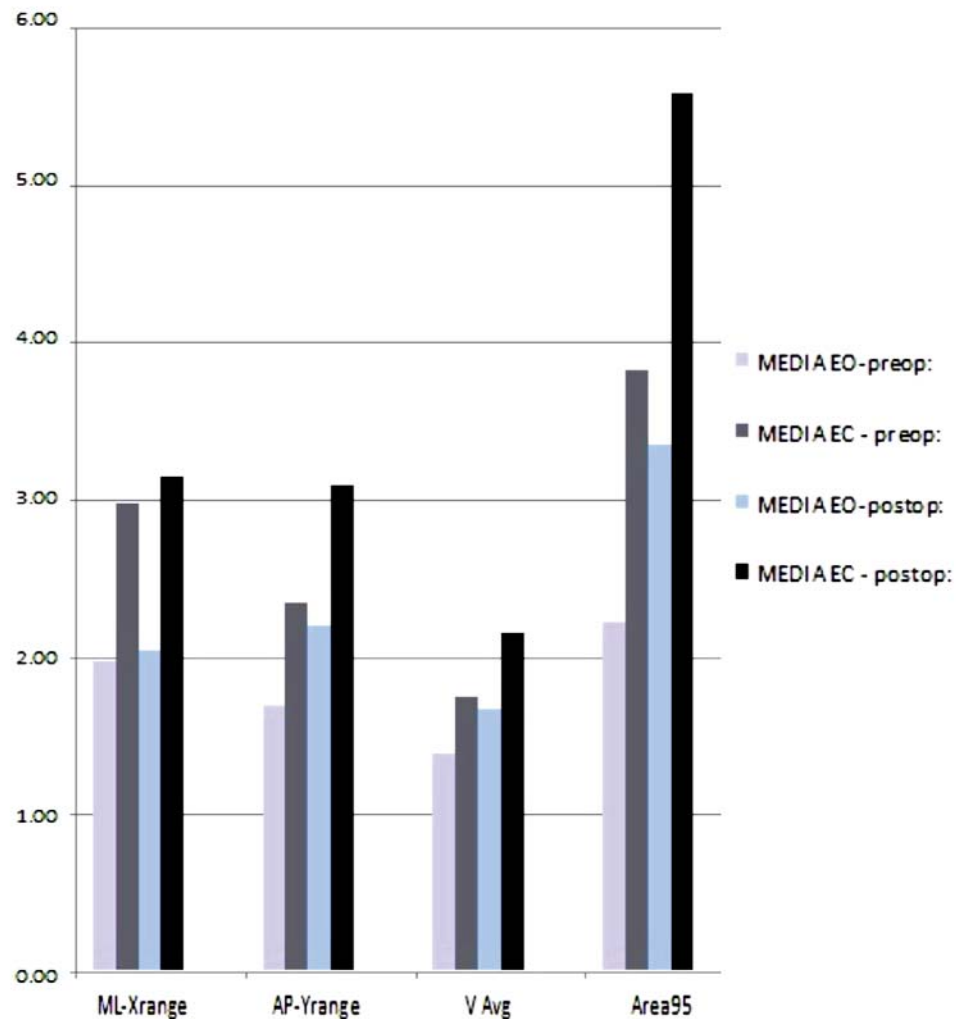


Figure 1. Mean values of displacements (ML-Xrange: mediolateral displacement; AP-Yrange: anteroposterior displacement; V Avg - average velocity; MEDIA EO- open eye mean; MEDIA EC- closed eye mean)

posterior displacement, “y” negative. The lateral right displacement was “x” positive, and left, “x” negative.

Statistical tests were performed using SPSS software, and Paired Samples Test was used to compare the results. The 0.05 level was used to denote statistical significance throughout testing.

Results

Open eye test. An insignificant mediolateral displacement increase ($p > 0.05$) of 3.4% was observed postoperatively, from a mean preoperative value of 1.97 ± 0.11 cm, to a mean postoperative value of 2.04 ± 0.14 cm.

A significant postoperative anteroposterior displacement increase ($p < 0.05$) of 23.2% was recorded, from a mean preoperative value of 1.69 ± 0.06 cm to a mean postoperative value of 2.20 ± 0.10 cm.

The average velocity also rose significantly ($p < 0.05$), by 16.8%, from a mean preoperative value of 1.39 ± 0.13 cm/s to a mean postoperative value of 1.67 cm/s.

The Elipse 95 grew significantly ($p < 0.05$), by 33.7%, from 2.22 cm², preoperatively, to 3.35 cm², postoperatively.

Closed eye tests. An insignificant mediolateral displacement increase ($p > 0.05$) of 5.1 % was observed postoperatively, from a mean preoperative value of 2.98 ± 0.12 cm, to a mean postoperative value of 3.14 ± 0.15 cm.

A significant postoperative anteroposterior displacement rise ($p < 0.05$) of 23.9% was recorded, from a mean preoperative value of 2.35 ± 0.10 cm to a mean postoperative value of 3.09 ± 0.12 cm.

The average velocity grew significantly ($p < 0.05$), by 19.1%, from a mean preoperative value of 1.74 ± 0.13 cm/s to a mean postoperative value of 2.15 cm/s.

The Elipse 95 increased significantly ($p < 0.05$), by 31.5%, from 3.82 cm², preoperatively, to 5.58 cm², postoperatively.

The results are summarized in *Table 1*.

The mean values of the studied parameters are presented in *Fig. 1*.

Discussion

For better understanding of the biomechanical alterations associated with lower extremity pathology, researchers and clinicians use three-dimensional gait analysis. Kinematics and kinetics analysis of different joints has allowed medical professionals to quantitatively evaluate the functional success of innovative rehabilitation strategies (11,12) or surgical techniques (13). Gait analysis is also an important tool in determining the influence of biomechanical factors on the progression of pathologies such as knee osteoarthritis (14).

Total knee arthroplasty is a common surgical procedure for the end stage of knee arthritis, providing long-term pain relief and patient satisfaction. Despite this, many TKA patients continue to have impairments and functional limitations when compared with age-matched controls (15). For instance, Walsh (16) has observed that one year after TKA, patients walked more slowly by 15% than age-

matched individuals without known knee pathology.

The vestibular and the visual system, the transfer of information from proprioceptors sited in tendons, muscles and the joint capsule, decrease with age, sometimes resulting in imbalance during standing and falls. Age, degenerative joint disease and joint replacement are demonstrated to be factors of the knee that deteriorate proprioception (17). Moreover, in case of knee osteoarthritis, the contralateral side is also affected by loss of proprioceptive function and deep sensibility, even when no signs of osteoarthritis are found on X-rays (18).

The influence of total knee arthroplasty on proprioception has been the subject of debate, as some authors report on benefits from this procedure (19,20), while others indicate that they did not observe any improvement (21,22). Severe knee osteoarthritis is characterised by pain and restricted mobility, muscle atrophy, and imbalance. Deficits in balance and coordination are caused by these conditions, whose importance for the safe performance of daily-life activities and for the prevention of falls has already been demonstrated (23). The anterior cruciate ligament, articular cartilage and menisci, among other many intra-articular structures of the knee joint, contain proprioception receptors. During TKA many of these structures are resected. However, additional proprioceptors are located outside the capsule in the tissue around the joint (24). Since they would be preserved during TKA, they could partially compensate the loss.

Pap et al. (21) found worse values for proprioception in the operated knee as compared to the contralateral one and compared to a control group 4.6 years after surgery. M. Gstoettner et al. detected no improvement in standing balance after TKA when no specific proprioceptive training had been performed (25). They also found that preoperative proprioceptive training in patients undergoing total knee replacement was effective in improving standing balance. Preserving soft tissue around the prosthesis is essential for a better proprioception. Also extensive soft tissue release could cause knee instability and misalignment (26).

Our study results prove the importance of sight in postural control. Thus, mediolateral and anteroposterior displacement, the average velocity and Elipse 95 had significantly ($p < 0.05$) higher values in closed eye trials than in open eye trials, both before and after surgery. Moreover, the Romberg coefficient showed supra-unitary values. The Romberg coefficient is the most widely-used index for assessing the influence of sight in postural performance studies, and represents the ratio between a considered parameter measured during a closed eye trial, and the same parameter measured during an open eye trial.

Excepting mediolateral displacement, all the other studied parameters showed significantly ($p < 0.05$) higher values in the postoperative period compared with the preoperative one, in both open and closed eye trials.

Conclusions

The study results demonstrate that balance control is weaker shortly after unilateral knee arthroplasty than in the

preoperative period for patients who did not undergo any proprioceptive training before surgery. Although proprioception is altered in osteoarthritic knees, the TKA procedure may additionally affect proprioceptors. Moreover, decreased muscular strength in the first days after TKA can also cause postural instability. These results must be completed and compared with those of subsequent assessments conducted after prolonged recovery program.

The post-TKA period is a sensitive one, considering that patients are elderly and postural control is already affected by age. The TKA causes additional instability in the days after the procedure, therefore the risk of falling injuries is higher in this period. Consequently, there is an imperative need to implement a recovery program as soon as possible after TKA. As other literature studies confirm that a proper bone stock creates the opportunity for a good cementation quality and longer survival rates for arthroplasties (27), also it is important that the functional outcome of these procedures should allow social reintegration of patients. The procedure must target not only a good survival rate for the implant but also a good functional outcome. This can be achieved with an appropriate rehabilitation program.

Conflicts of interest and source of funding

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