Dynamic Balance, Pain and Functional Performance in Cruciate Retaining, Posterior Stabilized and Uni-Compartmental Knee Arthroplasty

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Abstract**—**Background: With the perceived pain and poor function experienced following knee arthroplasty, patients usually feel un-satisfied. Yet, a controversy still persists on the appropriate operative technique that doesn't affect proprioception much.

Purpose: This study compared the effects of Cruciate Retaining (CR) and Posterior Stabilized (PS) total knee arthroplasty (TKA) and uni-compartmental knee arthroplasty (UKA) on dynamic balance, pain and functional performance following rehabilitation.

Methods: Fifteen patients with CRTKA (group I), fifteen with PSTKA (group II), fifteen with UKA (group III) and fifteen indicated for arthroplasty but weren't operated on yet (group IV) participated in the study. The mean age was 54.53±3.44, 55.13±3.48, 52.8±1.93 and 55.33±2.32 years and BMI 35.7±3.03, 35.7±1.99, 35.6±1.88 and 35.73±1.03 kg/m^2 for group I, II, III and IV respectively. The Berg Balance Scale (BBS), WOMAC pain subscale and Timed Up-and-Go (TUG) and Stair-Climbing (SC) tests were used for assessment. Assessments were conducted four and eight weeks pre- and post-operatively with the control group being assessed at the same time intervals. The post-operative rehabilitation involved hospitalization (1st week), home-based (2nd-4th weeks), and outpatient clinic (5th-8th weeks) programs.

Results: The Mixed design MANOVA revealed that group III had significantly higher BBS scores, and lower pain scores and TUG and SC time than groups I and II four and eight weeks post-operatively. In addition, group I had significantly lower pain scores and SC time compared with group II eight weeks post-operatively. Moreover, the BBS scores increased significantly and the pain scores and TUG and SC time decreased significantly eight weeks post-operatively compared with the three other assessments in group I, II and III with the opposite being true four weeks post-operatively.

Interpretation/Conclusion: CRTKA is preferable to PSTKA with UKA being generally superior to TKA, possibly due to the preserved human proprioceptors in the un-excised compartmental articular surface.

Keywords**—**Dynamic Balance, Functional Performance, Knee Arthroplasty, Pain.

I. Introduction

OSTEOARTHRITIS (OA) is the most common form of arthritis that affects adults over the age of 45 [1]. It affects all weight-bearing joints with the knee joint being the most commonly affected [2], [3]. Knee joint affection is associated with greater symptomatology than any of the other weight-bearing joints [2], [4]. Knee OA represents a major cause of pain and dysfunction, imposing an economic burden to the society. It was estimated that the total annual costs of OA is $89.1 billion. Furthermore, it was estimated that $3.4-13.2 billion of this sum is due to job-related OA solely, making job-related OA more costly than asthma and pulmonary diseases, and also more than renal and neurologic diseases combined [5].

To date, no cure for the disease exists. However, epidemiologic studies confirm that the onset and progression of the disease could be controlled through lifestyle modifications such as weight loss, increased physical activity and dietary changes [6]. Yet, joint replacement serves as a choice of treatment that is usually used in late stages of the disease. Of 490 000 arthroplasties performed in 2002 in the United States, 320 000 were conducted on the knee and 170 000 on the hip, with an estimated 43% increase in the number of procedures performed in 10 years [7].

Joint replacement could be either for the total knee (total knee arthroplasty, TKA) or one compartment (unicompartmental knee arthroplasty, UKA). KA was reported to be successfully able to improve proprioception [8] in particular TKA also reduces pain and provides a functional range of motion for patients with severe knee OA [9], [10]. Yet, about 15% of patients still report moderate to severe pain a year after TKA despite no evidence of radiographic abnormalities [11]. The dissatisfaction is usually related to the continuing pain and poor function [12], [13].

Despite the fact that TKA is being used with success, a controversy still persists on the appropriate technique of operation. Although both cruciate retaining (CR) and posterior stabilized (PS) TKA produced good to excellent scores in at least 90% of patients at long-term follow-ups [14]-[17], there is a debate whether to retain or resect the posterior cruciate ligament (PCL) in TKA. Those in favor of PCL retaining, as in CR TKA, believe that the PCL is beneficial for maintaining the antero-posterior stability of the joint post-operatively through preventing excessive posterior translation, producing normal knee kinematics especially femoral rollback, increasing joint range of motion, and improving joint proprioception and stair climbing ability [18], [19]. On the other hand, those in favor of PCL resection, as in PS TKA, believe that PS TKA has the advantages of being a less technically demanding procedure [20]-[22], that is associated with increased ranges of motion [20], [23], [24]. Moreover, PS TKA is preferable to CR TKA in patients in whom the PCL is

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damaged or cannot be balanced, or patients under-going revision total knee arthroplasty [25]. In a systematic review conducted by [25], the researchers concluded that although PCL retaining is a technically demanding procedure, it is associated with excellent long-term results considering placing the PCL under appropriate tension, during the procedure, such that the kinetic benefits of its retention can be gained and the adverse effects of its being excessively tight or lax can be avoided.

The controversy on whether or not to excise the PCL is further associated with a controversy on the effect of TKA on proprioception. References [26], [27] reported significant improvement in proprioception 3-6 months post-operatively while [28] reported significant reduction. Meanwhile, [29], [30] reported insignificant differences between replaced and un-replaced knees. Both controversies seek attention as they may be related since many of the intra-articular structures, altered or removed during TKA, have long been reported to be important for knee proprioception [31]-[33].

On another note, researchers continue to debate the relative merits of UKA and TKA. Since the anatomical structures are retained in UKA, especially the innervated cruciate ligaments, it is expected that the sensorimotor function (proprioception) would be superior after performing UKA [8]. Yet, the findings reported by [34] revealed insignificant difference in proprioception following both UKA and TKA.

Two methods of proprioception assessment were detected for describing functional deficits in arthritic knees; direct and indirect. The direct method involves joint-position sense assessment [35], [36], while the indirect involves balance assessment especially dynamic balance assessment [37], [38]. Most of the reviewed literature assessed the joint-position sense in KA [30], [34], [39]-[44], with few being conducted on assessing balance [8], [45]. Even for these few studies that examined balance, it was noticed that different groups were tested; either examining CRTKA and PSTKA [45], or examining CRTKA and UKA [8]. It is suggested that the differences among the conducted studies in the methods of proprioception assessment and/or the examined groups might be responsible for the differences in findings reported for the effect of KA, whether total or unicompartmental, on proprioception.

To the best of our knowledge, no study compared among the three operative techniques for dynamic balance. Accordingly, the main purpose of the current study was to compare among the UKA, CRTKA and PSTKA for dynamic balance, functional performance, and pain following a rehabilitation period. It is suggested that any improvement in either of proprioception or either clinical outcome may be reflected in improvement in the other since they are related [13], [46]-[48]. In this way, the dissatisfaction perceived by patients who have KA may be resolved.

II. Methods

A. Participants

Forty-five patients with unilateral KA participated in the study. They were divided into three groups of 15 patients each. Group I included those who had CRTKA, group II included those who had PSTKA, and group III included those who had UKA. All patients shouldn't have had any previous KAs with their present unilateral KA being conducted using the medial para-patellar approach. They were operated on and referred by the same surgeon. They followed the same post-operative hospitalization and home care programs. An additional group of 15 patients, serving as control (group IV) participated in the study. The control group included those who had unilateral moderate or severe knee OA (determined as grades III or IV using Kellgren and Lawrence scale [49]) and who were indicated for surgery but weren't operated on yet. Groups I, II, III and IV involved 9, 8, 8, and 8 females respectively and 6, 7, 7, and 7 males respectively. The age ranged from 50-70 years, and BMI 30-39 kg/m^{2}for all patients. Exclusion criteria involved having any previous knee or lower limb surgery, any disorder that affects balance (as peripheral neuropathy, vestibular system disorder, vertebro-basilar insufficiency and/or postural hypotension), any neurological disorder, any cardiac disease, diabetes, uncontrolled hypertension, BMI≥40 or any post-operative complication (as infection and/or loosening) for those who were operated on. All patients gave informed consents prior to participating in the study which was approved by Cairo's University supreme council of postgraduate studies and research.

B. Procedures

All patients were assessed for dynamic balance, functional performance and pain.

1. Dynamic Balance Assessment

Dynamic balance was assessed using the Berg Balance Scale (BBS) which was developed to be used with old people who have impairment in balance. It has a total score of 56 with higher scores indicating higher levels of independence. It has an inter-rater reliability of ICC=0.97 in patients with peripheral arthritis [50].

2. Functional Performance Assessment

Functional performance was assessed using the Stair Climbing (SC) and Timed Up-and-Go (TUG) tests. Considering the SC test, each patient was asked to ascend and descend a flight of five steps (18-cm high and 28-cm deep). The test was performed as quickly as possible while feeling safe and comfortable with one handrail being allowed if needed. The time required to perform the task was recorded in seconds. A decrease in the recorded time indicates improvement. A test-retest reliability of ICC=0.9 was reported for this test in patients with knee and hip OA [4].

Considering the TUG test, each patient was asked to rise from an armed chair (with a seat height of 46cm), walk 3m, turn and return to sit in the same chair. Patients were asked to walk as quickly as possible while feeling safe and comfortable. The chair arms were permitted to help in standing up and sitting down. The time required to perform the task was recorded in seconds. The TUG test assesses balance and mobility in old adults [51]. An intertester reliability of ICC=0.94-0.99 and intratester reliability of ICC=0.72-0.98 were reported for the TUG test in patients with knee OA [52].

3. Pain Assessment

Pain was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale. Excellent validity, reliability and responsiveness have been reported for the WOMAC pain subscale in patients with knee osteoarthritis [53].

The three experimental groups were assessed four times; 4 and 8 weeks preoperatively and 4 and 8 weeks postoperatively. Assessment was conducted twice pre-operatively for consistency. The control group was assessed four times at the same time intervals.

Following KA, patients underwent their rehabilitation that involved the same exercises that were conducted by [54]. The rehabilitation included three programs; an immediate post-operative program (hospitalization period), a home-based physical therapy program, and an outpatient clinic rehabilitation program.

The immediate post-operative program consisted of heel slides in supine-lying or sitting position to increase knee flexion, ice application for 15 minutes (performed twice per day), static quadriceps exercise, straight leg raising exercises, muscle-setting exercises for the quadriceps, hip extensors, hamstrings, and hip abductors, bed mobility and transfers usually initiated 24-48 hours post-operatively, ankle pumps to prevent secondary complications such as deep vein thrombosis, gravity-assisted knee extension in supine-lying position by periodically placing a towel roll under the ankle and leaving the knee unsupported, compressive wrap to control effusion and partial weight bearing by using a walker.

The home-based physical therapy program consisted of static exercises, active assisted and active knee range of motion exercises, daily living activities, patellar mobilization (grades I and II), isometric strengthening exercises for the hip abductors and adductors, active assisted progressing to active straight-leg raising in supine, prone, and side lying positions, gentle stretches for the hamstrings, calf, and iliotibial band, supine terminal knee extension from 30°-0°, walking (weight bearing as tolerated) with an assistive device, trunk/pelvis strengthening exercises.

The outpatient clinic rehabilitation program included interventions that are designed to control pain and swelling, stretching and patellar mobilizations to improve knee ROM, progressive high intensity volitional exercises to increase lower extremity strength, and training to improve functional ability. It consisted of patellar mobilization exercises, active-assisted flexion and extension exercises, passive knee extension, quadriceps and hamstrings setting exercises, straight leg raising exercises, terminal knee extension, multi angle isometric exercises for the quadriceps muscle, hip abduction and adduction exercises, knee flexion from standing, stretching exercises for the iliotibial band, hamstrings, gastrocnemius and soleus muscles.

The immediate post-operative program was conducted daily for the first post-operative week followed by the home-based physical therapy program that was conducted every other day starting from the second post-operative week to the fourth. Finally, the outpatient clinic rehabilitation program was conducted three times per week starting from the fifth post-operative week till the eighth. The control group also conducted the same rehabilitation programs. All programs were conducted by the same therapist.

C. Data Analysis

All statistical measures were performed using SPSS version 17 for Windows. Initially and as a pre-requisite for parametric analysis, data were screened for normality assumption through using Kolmogorov-Smirnov and Shapiro-Wilks normality tests, and testing for the presence of extreme scores and significant skewness and kurtosis. In addition, data were screened for homogeneity of variance assumption. Once data were found not to violate the normality and homogeneity of variance assumptions, parametric analysis was conducted. Mixed design MANOVA was used to compare among the four assessments (within-subject effect "time"), the four tested groups (between-subject effect "tested group") and the "time*tested group" interaction. The level of significance was set at $p<0.05$.

III. Results

Descriptive statistics revealed that the mean±SD values for the age were 54.53±3.44, 55.13±3.48, 52.8±1.9 and 55.33±2.32 years and the BMI were 35.7±3.01, 35.7±1.99, 35.6±1.88 and 35.73±1.03 kg/m^2 for groups I, II, III, and IV respectively with no significant differences among the groups for both the age and BMI.

The Mixed Design MANOVA revealed highly significant within-subject and between-subject effects together with significant time*tested group interaction ($p=0.000$). The within-subject effect revealed significant decreases ($p<0.05$) in the post1 BBS scores compared with the pre1, pre2 and post2 ones in the three experimental groups. However, there were significant ($p<0.05$) increases in post2 BBS scores compared with the pre1, pre2 and post1 BBS ones in the three experimental groups. There were no significant differences ($p>0.05$) in BBS scores among the four times of assessment in the control group.

Regarding the recorded time of the TUG and SC tests, it increased significantly ($p\leq0.001$) in the post1 compared with the pre1, pre2 and post2 measurements in the three experimental groups. However, there were significant ($p<0.05$) decreases in the post2 compared with the pre1, pre2 and post1 measurements in the three experimental groups. Regarding the recorded time in the control group, it decreased significantly ($p=0.000$) in each of post1 and post2 compared with pre1 and pre2 measurements. Meanwhile, it decreased significantly ($p\leq0.003$) in post2 compared with post1 measurements.

TABLE I
DESCRIPTIVE STATISTICS FOR THE BERG BALANCE SCALE (BBS) SCORES, TIMED-UP AND GO (TUG) AND STAIR CLIMBING (SC) TESTS' DURATION AND WOMAC PAIN SCORES IN THE CRUCIATE RETAINING, POSTERIOR STABILIZED, AND UNICOMPARTMENTAL KNEE ARTHROPLASTY AND CONTROL GROUPS FOUR AND EIGHT WEEKS PRE- AND POST-OPERATIVELY

Dependent variable	Tested group	Pre1	Pre2	Post1	Post2
BBS	Group I	33.31 ±1.25	33.38 ±1.71	23 ±4.1	43.62 ±3.5
	Group II	33.13 ±1.3	33.2 ±1.86	22.8 ±4.99	42.73 ±4.3
	Group III	33.47 ±1.88	33.4 ±1.76	28.27 ±2.28	51 ±2.85
	Group IV	33 ±1.31	33.07 ±0.8	33.8 ±0.94	35.27 ±0.8
TUG (s).	Group I	73.15 ±3.41	73 ±3.76	88.69 ±3.97	28.54 ±3.2
	Group II	73.8 ±2.54	73.8 ±2.68	88.8 ±4.09	31.2 ±2.88
	Group III	73.87 ±3.11	74 ±3.27	77.6 ±2.16	21 ±1.96
	Group IV	73.67 ±2.53	73.53 ±2.29	65.6 ±2.26	61.87 ±2.36
SCT (s).	Group I	76.54 ±1.66	76.92 ±1.61	91.31 ±3.09	34 ±2.27
	Group II	77.93 ±2.25	77.93 ±2.74	91.93 ±3.95	38.73 ±3.13
	Group III	77.67 ±2.16	77.73 ±2.09	84.73 ±1.49	23.13 ±3.02
	Group IV	77.47 ±1.46	77.6 ±1.96	66.27 ±2.05	61.6 ±2.32
Pain	Group I	11 ±0.82	11.08 ±0.86	15.92 ±1.32	4.23 ±0.83
	Group II	11.13 ±0.64	11.13 ±1.06	15.47 ±1.06	6.2 ±0.86
	Group III	11 ±0.76	11.07 ±0.7	11 ±1.56	2.33 ±0.82
	Group IV	11.07 ±0.8	11.07 ±0.8	7.8 ±0.77	7.2 ±0.77

BBS: Berg Balance Scale, TUG: Timed-Up and Go test, SC: Stair Climbing test, (s): seconds
Pre I: Eight weeks pre-operatively, Pre II: four weeks pre-operatively, Post I: four weeks post-operatively, and Post II: Eight weeks post-operatively
Group I: Cruciate Retaining Total Knee Arthroplasty, Group II: Posterior Stabilized Total Knee Arthroplasty, Group III: Unicompartmental Knee Arthroplasty, and Group IV: Control Group

Considering pain assessment, the WOMAC pain subscale scores increased significantly ($p<0.05$) in the post1 compared with the pre1, pre2, and post2 measurements in groups I and II.

However, there were significant ($p<0.05$) decreases in the post2 compared with the pre1, pre2 and post1 measurements in the three experimental groups. Finally, there were significant ($p<0.05$) decreases in each of post1 and post2 compared with pre1 and pre2 measurements in the control group.

Considering the between-subject effect, it revealed that group III had significantly ($p\leq0.001$) increased BBS score, decreased TUG and SC time and decreased WOMAC pain scores compared with group I and II four and eight weeks post-operatively. Meanwhile, group IV had significantly ($p\leq0.009$) increased BBS score, decreased TUG and SC time and decreased WOMAC pain scores compared with group I, II and III four weeks post-operatively.

In contrast to the results reported four weeks post-operatively, group IV had significantly ($p<0.05$) decreased BBS score, increased TUG and SC time and increased WOMAC pain scores compared with group I, II and III eight weeks post-operatively. Finally, group I had significantly ($p<0.05$) decreased SC time and WOMAC pain scores compared with group II eight weeks post-operatively. Table I shows the mean±SD scores for the BBS, TUG and SC tests and WOMAC pain subscale in the tested four groups pre- and post-operatively.

IV. DISCUSSION

The within-subject findings revealed that there were significant decreases in the BBS scores, and increases in the TUG and SC time four weeks post-operatively compared with the three other assessments in the three experimental groups. This decline in dynamic balance and functional performance may be related to joint effusion, and removal of the affected articulating surfaces of the knee joint and replacing them with artificial components suitable for each patient which affects proprioception [55]. The decline in functional performance four weeks post-operatively is supported by the findings reported by [56], [57], however, it should be noted that they examined patients with TKA only.

The decline in dynamic balance and functional performance four weeks post-operatively was further associated with a significant increase in the WOMAC pain scores, indicating pain worsening, compared with the three other assessments. This occurred in groups I and II only.

As opposed to the findings reported four weeks post-operatively, the statistical analysis revealed that there were significant increases in the BBS scores, decreases in the TUG and SC time, and decreases in WOMAC pain scores eight weeks post-operatively in the three experimental groups compared with the other three assessments. This improvement may be due to the corrected knee deformity and regained normal alignment, and removal of osteophytic lippings [55]. Similar findings were reported by [45], [58], [59] although assessment was conducted at different time intervals. Reference [45] reported significant improvement in both dynamic balance and postural control 12 months post-operatively. Both balance and postural control were assessed using computerized posturography. In the same context, [58] found that their patients who had TKA performed significantly better on the SC test, but not on the TUG, 12 months compared with 3 months post-operatively. Finally, [59] assessed functional performance at several time intervals. They used the Lower Extremity Functional Scale and the 6-

minute walk test for assessment. The greatest improvement occurred in the first 12 weeks post-operatively. Slower improvement continued to occur 12-26 weeks post-operatively with little improvement occurring beyond 26 weeks.

In particular, the conducted rehabilitation program is strongly suggested to have been responsible for the improvement in perceived pain and performed function. This is evidenced by the findings reported for the control group who showed significant decreases in the TUG and SC time and WOMAC pain scores that were recorded at time intervals similar to the post-operative four and eight weeks for the experimental groups. This occurred after undergoing the same rehabilitation programs that were conducted for the three experimental groups. Similar findings were reported by [53], [60]-[63] who reported that strengthening exercises decrease pain and stiffness and improve self-reported function in individuals with knee OA.

Regarding the between-subject findings, they revealed that group III had significantly increased BBS scores, decreased TUG and SC time and decreased WOMAC pain scores four and eight weeks post-operatively compared with groups I and II. This might be due to the preservation of the knee joint cruciate ligaments and to the less affection of proprioception with one compartment only being excised. The cruciate ligaments are important for dynamic proprioception. Large loads are exerted across the knee joint during activity. These loads that result from both external loads and muscle forces stretch the ligaments that are involved in dynamic proprioception. Accordingly, after UKA, the cruciate ligaments functions normally whereas after TKA they don't. This was suggested to be the cause for the better dynamic proprioception recorded in UKA compared with TKA in the study conducted by [8]. The researchers found that the postural sway improved in UKA as twice that in TKA, although this was reported 6 months post-operatively [8].

On another regard, the findings revealed that group I had significantly decreased SC time and WOMAC pain scores eight weeks post-operatively compared with group II with no significant difference in between for the dynamic balance. This might be related to the preserved PCL in group I. The PCL is needed for ascending and descending stairs as it controls and prevents excessive backward rolling of the femur. Accordingly, its absence is accompanied with excessive rolling with an increased demand on the quadriceps muscle especially after 45° flexion [64]. The insignificant difference between groups I and II for the dynamic balance matches with the findings reported by [30], [34], [41]. However, the significant difference reported for the pain and functional performance is opposed by the finding reported by [65].The opposition may be related to the different tested sample and scale. They tested patients having CR TKA in one limb and PS TKA in the other and they used the Knee Society scale for assessing performance.

Finally, findings revealed that the three experimental groups had significantly increased BBS scores, decreased TUG and SC time, and decreased WOMAC pain scores eight weeks post-operatively compared with the control one with the opposite being true four weeks post-operatively. The recorded eight-week post-operative improvement might be again related to the corrected knee deformity and regained normal alignment, and removal of osteophytic lippings [55].

V. Conclusion

CRTKA is preferable to PSTKA with UKA being generally superior to TKA, possibly due to the preserved human proprioceptors in the un-excised compartmental articular surface.

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