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Effect of Immediate Weight-Bearing on Patterns of Gait and Falling Risk after Tibial Plateau Fractures: A retrospective Study

Osama Khalil Mohamed Khalil*

Department of Orthopedic Surgery, Damietta Specialized Hospital, Ministry of Health, Damietta, Egypt..

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ABSTRACT

Background and aim: Treatment of tibial plateau fractures are challenging due to changes in gait and increased the risk for falls. Early weight bearing may affect outcome. However, there was no consensus on early weight bearing. Thus, this study was designed as a retrospective study to determine the differences in gait patterns and risk of falling after surgery for fixation of tibial plateau fractures (grades I to IV Schatzker classification).

Methodology: We collected data about gait patterns and the risk of falling after surgery for tibial plateau fractures. The study included data of 122 patients. All were treated by open reduction and internal fixation with locking plates and screws. Patients were categorized into two equal groups. The first of immediate weight bearing and the second for non-weight bearing group. The final outcome was determined at the end of the third month after surgery. This included data about isometric muscle strength, mobility and balance (at the hip), calculation of Tinetti Performance Oriented Mobility Assessment (POMA) score and fall risk was graded as (minimal if POMA > 23; moderate for scores between 19 and 23, and high for scores lower than 19).

Results: Most patients were in their fifties (the age ranged between 21 to 60 years). Males were predominant in both groups (73.8% and 67.2% in A and B groups). Both groups were comparable regarding patient age, sex, body mass index (BMI), fracture grade and type. The weight bearing group was associated with significant increase of step symmetry, step continuity, path, trunk stability, walking stance, gait, balance and total POMA scores. The gait score, balance score and total POMA scores were 11.049±1.986, 14.672±2.631 and 25.721±3.271 in weight bearing group, compared to 9.246±2.078, 11.098±2.406 and 20.409±3.153, successively. The risk of fall was significantly different between weight bearing than non-weight bearing groups. It was high, medium and minimal in 0.0%, 23.0% and 77.0% respectively in wight bearing, compared to 32.8%, 49.2% and 18.0% respectively in the non-weight bearing group ($p < 0.001$). The fall risk was significantly correlated with stride length, velocity, path score, gait and balance scores.

Conclusion: The immediate weight bearing after surgical treatment of tibial plateau fractures is associated with reduced risk of fall and significant improvement of spatiotemporal gait parameters.

Keywords: Gait; Balance; Fall; Tinetti Performance Oriented Mobility Assessment; Schatzker classification.

* Corresponding author
Email: Dr.osama.khalil78@gmail.com

INTRODUCTION

Direct and indirect compressive forces (of High and low energy) could lead to tibial plateau fractures. These included different bone injuries, soft tissue injury and ligamentous disturbance. Plain radiography showed fat-fluid level in suprapatellar bursa, mal-alignment of femoral condyles and tibial edges, with increased trabecular density in the lateral epicondyle. When tibial plateau fractures were suspected with negative X-ray, patients must be submitted to computerized tomography. The treatment is surgical intervention for fixation of fractures [1-3]. Complications after TP fractures surgery commonly include abnormalities of the gait and increased risk for falling [1, 4,5].

Locked plates (single lateral or dual) are used by most surgeons to provide stability required to allow early range of motion (ROM) is a safe manner [6-9]. The postoperative wight-bearing protocols after fixation of tibial plateau fractures are controversial [10-12].

The traditional management protocol after surgery for tibial plateau fractures includes a long period (up to 12 weeks) of non-weight or partial weight bearing. However, other researchers advocate early weight bearing [13-15]. Those advocates the long period of partial or non-weight bearing after surgery said that the early initiation of rang of motion (ROM) before wound healing may increase the risk of wound complications. In addition, they added, this does not offer any long-term benefits [16]. However, other researchers demonstrated multiple benefits for early weight bearing after tibial plateau fractures surgery. These included improved muscular strength, better outcome and faster recovery of the gait [17, 18].

Altered gait as a complication of tibial plateau fracture surgery is attributed to residual joint instability or muscle weakness, with inevitable uneven load distribution during walking [19-22]. In addition, gait abnormalities increased the risk of falls, especially with significant differences in muscle strength and stability between affected and non-affected limbs. The changes after TP fractures surgery include spatiotemporal (speed, stance time, step length), kinematic (joint ROM) and kinetic variables (muscular power) between affected and non-affected limbs [23].

Aiming to achieve faster recovery, the postoperative treatment (rehabilitation) protocols should plan to set the weight-bearing at the higher end of the spectrum, quick build of muscle strength, faster return to pre-operative gait pattern. However, this must be accomplished in a safe way to avoid hardware failure or loss of reduction [13, 24-26].

Due to absent consensus or guidelines for early weight bearing, postoperative protocols after tibial plateau fractures are tailored for each patient (planned individually) in our facility. Thus, we intended to determine the differences in gait patterns and risk of falling after surgery for fixation of tibial plateau fractures (grades I to IV according to Schatzker classification).

PATIENTS AND METHODS

Study setting and population: This was a retro-spective study, which included collection of data of gait pattern and the risk of falling after surgery for tibial plateau fractures. We finally included the data of 122 patients in the statistical analysis to increase validity of the results. All patients (their data) were selected from Damietta Specialized hospital from those attending the facility for treatment of tibial plateau fractures, during the duration between October 2019 to March 2021. All were treated by open reduction and internal fixation.

Inclusion and exclusion criteria

The inclusion criteria were 1) patient age 18 to 60 years of age, 2) man or women, 3) with confirmed diagnosis of tibial plateau fracture, 4) treatment by surgical intervention with fixation by plates and screws 5) fracture grades I to IV according to Schatzker classification, 6) and data of the postoperative follow up visit at 3 months were available. On the other hand, exclusion criteria were 1) Bicondylar fractures (due to its complexity and their need to extensive surgical manipulations) with ligamentous injury, 2) concomitant injuries, which prevent the use of crutches or weight bearing, 3) surgical complications prevented the immediate ambulation, and 4) pre-injury non-ambulatory patients.

Ethical aspects: The patient's consent was non-applicable. However, the anonymity of the patient is guaranteed. In addition, administration consent to collect data was obtained from the facility manager. The data was treated and the study flowed the Helsinki declarations for study conduct and reporting.

The data collected for patients were divided into two groups. The first of immediate weight bearing and the second for non-weight bearing group. We intentionally collected sufficient data to ensure equal distribution of both groups (each 61 patients)

Three months after surgery, we collected data about isometric muscle strength, mobility and balance (at the hip).

Postoperative protocols

In the weight bearing group (first group) patients were permitted an immediate, unrestricted weight- bearing as soon as the pain permits from the first postoperative day. However, the non-weight bearing group postoperative protocol included a six-week non-weight-bearing protocol as described in previous literature [13]. The same rehabilitation protocols were provided to all patients (in both groups) from the first postoperative data. This included home based exercises (daily) as prescribed by the rehabilitation specialists. In addition, all patients attended two physical therapy sessions at 2 and 6 postoperative weeks. Follow-up visits (face to face) and phone calls (twice a week till the end of the 3rd postoperative month) were made by rehabilitation specialists. At the last follow up visit (3 months postoperatively), video about the gait was captured by a mobile camera. The strength of hip muscles was measured and recorded and finally, the **Tinetti Performance Oriented Mobility Assessment (POMA)** was recorded.

Gait Experimental set-up: The medical tape affixed high-contrast markers to bony landmarks one of the physical therapists palpated. The landmarks included the lateral aspect of the knee in the mid-axial line at the patella level, the lateral malleolus, and the greater trochanter. One high-definition digital recording camera was used. We recorded the left- or right-side sagittal plane and frontal views of the walking. The camera was adjusted to fit the entire body within the frame of view with space available for motion (usually achieved when set at a perpendicular plane to the patient at 2.5 m and 1 m above the floor). Patients then walked at their self-selected pace along a 3-m marked walkway with neither a leg brace nor an assistive device. Right and left views were captured for each patient. A physical therapist with a biomechanics/ kinesiology degree analyzed the data using the available open-license video analysis software to compute several spatiotemporal gait measurements.

Outcomes measures

Gait measurements:

Spatial Gait Parameters included the step length, stride length and step width. The step length was calculated as the distance between the heel contacts of two feet in a sequence. However, the stride length was measured as the anterior-posterior distance between the heels of two consecutive footprints of the same foot. In addition, the step width was calculated as the distance between the heel and the contralateral heel at each heel contact in the mediolateral direction.

Temporal Gait parameters included the step frequency (cadence), single support time, step time, and stride time. The step frequency was defined as the total number of steps taken per minute. However, the single support time was defined as the period when only one foot is on the ground, corresponding to the swing phase of the contralateral leg. The step time calculated as the time taken to complete a heel strike of the ipsilateral foot and then the heel strike of the contralateral foot. Furthermore, the stride time was defined as the time required to complete an entire gait cycle.

Spatiotemporal Parameters included gait speed, mobility assessment, and hip stability strength. The gait speed is defined as the distance covered in a specific time (m/s). The expected normal range was set at 1.2 to 1.4 m/s. The POMA questionnaire was used to assess mobility (functional recovery and balance). The balance domain was assessed by tasks like sitting, standing and turning with assessment of static and dynamic balance. The second domain (functional recovery) focused on gait, evaluation of walking quality (step symmetry, continuity, trunk stability). Each domain maximum score was 28, and higher scores indicated better mobility and lower risk for falling. However, score < 19 are associated with a high risk of falls. The questionnaire was validated for Egyptian orthopedic surgeries previously [27]. **Hip muscle strength** was measured as the isometric strength for abductors, flexors, and extensors using a handheld dynamometer.

Statistical analysis: the collected data were introduced to software computer package for analysis. Quantitative data were summarized by their arithmetic means, standard deviation (SD), and sometimes their minimum and maximum values. The qualitative data were expressed by their relative frequency and percentage in each group. Groups were compared by independent samples “t” and Chi square tests for quantitative and qualitative data respectively. Correlation coefficient (r) was calculated and graded (mild, < 0.3, moderate (0.3 to 0.7) and powerful for more than 0.7 to reach complete correlation at the value of 1.0). P value < 0.05 was considered significant.

RESULTS

The current work was a retrospective collection of data about the effect of early weight bearing after treatment of tibial plateau fractures on the risk of falls. Two groups were assigned (each 61 patients). Most patients were in their fifties (the age ranged between 21 to 60 years). Males are predominant in both groups (73.8% and 67.2% in groups A and B respectively) with no significant difference between groups. In addition, both groups were comparable as regards patient’s body mass index (BMI), fracture grade according to Schatzker classification system and fracture type according to 3 columns classification **(Table 1).**

The spatiotemporal gait measurements showed significant reduction of step length (cm) in both affected and non-affected limbs (44.75±17.44 and 34.57±4.96 vs 52.92±8.72 and 47.62±9.13 respectively). In addition, stride length and single limb stance time at the affected side were significantly reduced in non-weight bearing than weight bearing groups (79.32±18.27 and 100.54±11.64 vs 0.265±0.083 and 0.436±0.054, respectively). However, the single limb stance time on the non-affected limb was significantly increased in non-weight bearing than weight bearing groups (0.525±0.127 vs 0.457±0.059). In addition, stride width was significantly reduced on weight bearing than non-weight bearing groups (7.393±1.952 vs 10.574±2.771). Furthermore, step time on the non-affected limb and velocity were significantly higher in weight bearing than non-weight bearing groups (0.677±0.141 and 0.737±0.111 vs 0.604±0.146 and 0.541±0.194, respectively). However, no significant differences were recorded for double limb support either in phase 1 or 2, step time on the affected limb stride time and step frequency (Cadence) **(Table 2).**

Regarding gait balance outcome, the weight bearing group was associated with significant increase of step symmetry score, step continuity score, path score, trunk stability score, walking stance score, gait score, balance score and total POMA score. However, the initiation of gait and foot clearance score showed non-significant differences. The gait score, balance score and total POMA scores were 11.049±1.986, 14.672±2.631 and 25.721± 3.271 in weight bearing group, compared to 9.246±2.078, 11.098±2.406 and 20.409±3.153, successively **(Table 3).**

According to total POMA score, the risk of fall was significantly different between weight bearing (group A) than non-weight bearing group (Group B). It was high, medium and minimal in 0.0%, 23.0% and 77.0% respectively in wight bearing, compared to 32.8%, 49.2% and 18.0% respectively in the non-weight bearing group ($p < 0.001$) **(Table 4).**

The total POMA score showed significant positive correlation with stride length, velocity, path score, gait and balance scores. But the correlation was inverse and significant with stride width. Other variables showed non-significant correlation with POMA score **(Table 5).**

Table (1): Comparison between groups regarding patient and fracture characteristics.

Variables		Group A (WB) (n=61)	Group B (NWB) (n=61)	Test	p
Age (years)	Mean±SD	41.77±10.13	40.13±12.20	0.807	0.421
	Min. – Max.	24-60	21-59		
Sex (n, %)	Male	45(73.8%)	41(67.2%)	0.630	0.427
	Female	16 (26.2%)	20(32.8%)		
BMI (kg/m^2)	Mean±SD	26.36±1.51	26.51±1.69	0.512	0.609
	Min. – Max.	21.71-29.41	22.66- 31.67		
Fracture grade Schatzker	I	18(29.5%)	13(21.3%)	2.964	0.397
	II	15(24.6%)	18(29.5%)		
	III	10(16.4%)	16(26.2%)		
	IV	18(29.5%)	14(23.0%)		
Fracture type (3 columns) (n,%)	Zero	12(19.7%)	20(32.8%)	4.100	0.129
	One	30 (49.2%)	20(32.8%)		
	Two	19 (31.1%)	21 (34.4%)		

Table (2): Comparison between groups regarding spatiotemporal gait measurements

Variables		Group A (WB) (n=61)	Group B (NWB) (n=61)	Test	p
Step length (cm)	Affected limb	52.92±8.72	44.75±17.44	*3.27*	*0.001**
	Non-affected limb	47.62±9.13	34.57±4.96	*9.80*	*<0.001**
Stride length (cm)		100.54±11.64	79.32±18.27	*7.64*	*<0.001**
Single limb stance time (s)	Affected limb	0.436±0.054	0.265±0.083	*13.41*	*<0.001**
	Non-affected limb	0.457±0.059	0.525±0.127	*3.73*	*<0.001**
Double limb support	Phase 1	0.244±0.074	0.257±0.066	1.02	0.308
	Phase 2	0.257±0.150	0.287±0.153	1.10	0.272
	Total limb stance time	0.501±0.173	0.544±0.171	1.39	0.166
Step time (s)	Affected limb	0.649±0.162	0.689±0.138	1.44	0.153
	Non-affected limb	0.677±0.141	0.604±0.146	*2.77*	*0.006**
Stride time		1.326±0.265	1.293±0.221	0.741	0.460
Velocity (m/s)		0.737±0.111	0.541±0.194	*6.85*	*<0.001**
Cadence (step frequency)		85.85±11.12	88.95±11.83	1.49	0.139
Stride width (cm)		7.393±1.952	10.574±2.771	*7.32*	*<0.001**

Table (3): Gait and balance outcome at the 3 months follow up visit among study groups

Variables	Group A (WB) (n=61)	Group B (NWB) (n=61)	Test	p
Initiation of gait score	0.908±0.167	0.863±0.086	1.858	0.066
Foot clearance score	1.912±0.229	1.934±0.274	0.501	0.617
Step symmetry score	0.923±0.190	0.521±0.187	*11.73*	*<0.001**
Step continuity score	0.941±0.194	0.693±0.187	*7.15*	*<0.001**
Path score	1.955±0.337	1.503±0.441	*6.36*	*<0.001**
Trunk stability score	1.903±0.167	1.301±0.411	*10.58*	*<0.001**
Walking stance score	0.787±0.334	0.438±0.234	*6.67*	*<0.001**
Gait score	11.049±1.986	9.246±2.078	*4.87*	*<0.001**
Balance score	14.672±2.631	11.098±2.406	*7.82*	*<0.001**
Total POMA score	25.721±3.271	20.409±3.153	*9.128*	*<0.001**

Table (4): Comparison between study groups regarding risk of falling according to POMA score

POMA grading of falling risk	Group A (WB) (n=61)	Group B (NWB) (n=61)	Total	Test	p
High	0(0.0%)	20 (32.8%)	20 (16.4%)	*48.163*	*<0.001**
Medium	14(23.0%)	30 (49.2%)	44 (36.1%)		
Low (minimal)	47 (77.0%)	11 (18.0%)	58 (47.5%)		

Table (5): Correlation between total POMA score and other variables

	Total POMA score	
	r	p
Age	0.156	0.086
BMI	-0.010	0.911
Fracture grade (Schatzker)	-0.038	0.676
Fracture type (3 Columns)	0.076	0.405
Stride length	*0.407*	*< 0.001**
Total double limb stance time	-0.111	0.225
Stride time	0.110	0.227
Velocity	*0.353*	*< 0.001**
Cadency (step frequency)	-0.169	0.063
Stride width	*-0.408*	*< 0.001**
Path score	*0.403*	*< 0.001**
Gait Score	*0.689*	*< 0.001**
Balance Score	*0.852*	*< 0.001**

DISCUSSION

Abnormal gait patterns are commonly reported after surgical treatment of tibial plateau and shaft fractures. These abnormalities showed improvements within 3-6 months after surgery [13, 28, 29]. These abnormalities are due to changes in range of motion of the joint with changes in muscle strength and activation [30,31].

The current study retrospectively evaluated the effect of early weight bearing after tibial plateau fractures. Data about two groups of (wight bearing and non-weight bearing) were collected. The final assessment data were obtained 3 months after surgery. The idea about early weight bearing is the known effects to facilitate the muscular isometric activation of muscles around the knee joint. In addition, early weight bearing reduced the effusion around knee joint with changes of joint loading providing nourishment for the cartilage [11, 14, 32-34].

The results of the current study revealed that weight bearing was associated with lower risk for falling and significant changes of spatiotemporal gait measurements. In addition, the POMA score for falling risk is significantly correlated with stride length, velocity, path score, gait and balance scores. But the correlation was inverse and significant with stride width. The weight bearing group spent more time on the affected leg during single-leg stance. This led to increased time for the non-affected limb. The situation is inverse to the non-weight bearing group. To avoid pain during weight bearing, the patient tends to incline and consequently register a shorter duration of the single leg stance on the affected than non-affected side in both weight bearing and non-weight bearing groups. These results agree with previous studies in literature [11, 35].

In addition, the inclination to avoid pain is associated with a shorter step length on the normal side than the affected limb. However, weight bearing group achieved step time and symmetrical step times closer to the normal range by the end of the third month after surgery. These results are in line with those of **Hollman et al. (36).** However, other studies reported contradictory results with longer duration of the mean step time at the end of postoperative sixth month [37,38].

The double limb support (phases 2 and total time) was lower in weight bearing than non-wight bearing groups. However, the difference was statistically non-significant. However, this may lead to reduced balance in non-wight bearing group. Double limb support is a known risk factor for fall due to fatigue and high energy expenditure during walking. This may lead to a less active lifestyle, which may affect gait patterns after surgery [39].

In addition, the early weight bearing is associated with faster walking than non-weight bearing group. However, the non-weight bearing was associated with wider steps that need more mechanical work to preserve the bodies lateral motion. Wider steps increased the mediolateral stability and reduced the anterior-posterior stability margin, with increased efforts to redirect the center of mass velocity. This was reduced with achievement of stable lateral foot placement with reduced step width. This reflects the importance of hip muscle's role in mediolateral and anteroposterior foot placement while walking in healthy adults [40-43].

The weight bearing group had higher gait and balance POMA scores than the non-weight bearing group. These results are in line with previous studies of **Maki (44) and Verghese et al. (45),** who reported that, the lower stride length, slow velocity, higher double-support time, lower gaits scores and stride width are due to fear and higher risk of falling

Our results showed that early weight bearing was associated with more stable trunk, longer step length, less step width and better balance and better gait scores. This was reflected in a reduced fall risk determined by POMA scores. These results are in line with previous study of **Gallagher et al.** [46]

In conclusion, the immediate weight-bearing after surgical treatment of tibial plateau fractures (Schatzker I-IV) led to significant improvements in spatiotemporal gait parameters and is associated with reduced risk of fall. Interestingly, this was achieved without interference with fracture reduction and its quality. This reflected potential safety and clinical advantages of early weight bearing after surgical treatment of tibial plateau fractures (Schatzker I-IV). We advocated early weight bearing. However, the study had some limitations. These include retrospective nature with liability to bias, absent gait variability measurements and monitoring of patient compliance to weight-bearing instruction. The results must be translated in line with these limitations. We recommend future in-depth studies to validate and generalize our results.

Conflict of interest: None

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