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ORIGINAL STUDY

The proprioception of the knee joint following tibia plateau fractures

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Proprioception is a conscious and/or unconscious perception of position change in an extremity or joint in space. In our study our purpose was to evaluate whether the lower extremity proprioception in long term, is altered following tibia plateau fractures and to assess its relation with age and type of fracture.

This retrospective study includes the evaluation of proprioception in 38 tibia plateau fracture patients (29 male, 9 female) of various types who were operated with open reduction and internal fixation (ORIF) technique in our clinic, by comparison of both operated knee and unaffected knee. The mean age of the patients were 38,8 (range, 20-60) and mean follow-up time was 56 months (range, 13-120 months). Proprioception measurements were assessed at 30° and 60° of knee flexion degrees both passively and actively.

There were no significant difference between the operated knee and unaffected knee by mean absolute angular deviation values at passive (p = 0,22) or active 60° (p = 0,22). Accordingly passive (p = 0,47) and active 30° (p = 0,62) mean absolute angular deviation values showed no significant difference.

Our study has indicated that proprioception at the operated extremity is not significantly different from the unaffected knee in tibia plateau fractures at long term follow-up.

Keywords : Proprioception ; Tibia plateau fractures ; Isokinetic dynamometer.

INTRODUCTION

Proprioception is simply defined as the conscious and/or unconscious awareness ability of the position of body parts in space. It is essential in perception of movements, muscle control and joint stability *(30,17,22,12)*. Each component of the knee joint at lower extremity contributes to form this sensation. The numerous mechanoreceptors of skin, muscles, tendons, menisci, joint capsules and ligaments take part in proprioception *(9)*. Proprioception studies in the literature most commonly involve post-ACL repair and post-knee arthroplasty *(28,1)*. To our knowledge no studies on knee proprioception following tibia plateau fractures have been reported.

As tibia plateau fractures are intra-articular fractures of the knee, they have great potential

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to become a threat to all structures forming the knee joint *(26)*. In tibia plateau fractures, from chondral to muscular, all structures can be injured by the traumatic effect *(23,31,8)*. This injury may potentially affect various functions of the knee as well as proprioception sense theoretically.

In our study we tried to address the question whether the lower extremity proprioception can be altered following tibia plateau fracture and also its relation with age and type of fracture.

MATERIAL AND METHOD

After approval of the institutional review board, the records of 174 patients with tibia plateau fracture that were managed by ORIF and have adequate follow-up data in our center between 2002-2013 were assessed retrospectively. Exclusion criteria of the study were:

1- Malunion or non-union after surgery

2- Patients with additional fractures at the same site

3-Patients who had high energy trauma with multiple injuries

4-Patients who had physical therapy during follow-up.

Of them 45 patients were randomly selected regarding Schatzker classification of tibia plateau fractures and asked for a last follow-up to assess physical examination and proprioception. 38 patients (29 male, 9 female) were attended and informed for the procedure. Range of motion in both knee joints were noted. Anteroposterior and lateral roentgenograms of the both knee joints, KSS Knee Scores, KSS Functional Scores, HSS Scores were collected and noted. Patients were informed about the proprioception measurement technique and a sports medicine specialist performed the measurements. The specialist was not informed about the operated site. Proprioception measurements (active and passive repositioning) were done by the isokinetic dynamometer (HUMAC® NORMTM Testing & Rehabilitation System, USA)

Knee joint proprioception measurement: The measurements were completed by isokinetic dynamometer under control of a test performer. The evaluation of proprioception in the knee joint was performed actively or passively. Sensation of position is a test that relies on patients' active and passive re-sensation of a particular angle that has been previously indicated by the examiners. Passive knee position sense was measured by the continuous passive movement (CPM) mode of the isokinetic dynamometer (HUMAC® NORMTM Testing & Rehabilitation System, USA) at the velocity of 20/second. The test was applied in sitting position and blindfold to prevent visual stimuli and to maintain concentration. (Figure 1) Range of motion from 0° to 90° for each patient was determined. Passive test was applied within 0° to 90° in CPM mode at the velocity of 20/second. At 30° and 60° of knee flexion the patients were given a stimulus and asked to indicate at the same degrees during 0° to 90° motion. Active repositioning test was performed similarly except in CPM mode. The tests were applied to both lower extremities. Measurements were tripled to prevent incompatibility.

Evaluation of proprioception:

The test performer noted the mean angular values at each test, these values were extracted from actual target angular values and absolute standard deviation was found. Negativity and positivity of the values were ignored. The results at passive 60°, active 60°, passive 30°, and active 30° were noted at operated and unaffected knees, which the examiner was, blinded which sides were operated.

Fig. 1. — A demonstrative view of proprioception measurements, which were done by the isokinetic dynamometer (HUMAC® NORMTM Testing & Rehabilitation System, USA). Active and passive sensation of the patients at 30° and 60° were evaluated.

The patients were grouped according to age as > 40 and < 40 years old and further grouped according to type of fracture as Schatzker type V and type VI. Latest standing anteroposterior and lateral radiographic views were evaluated by Kellgren & Lawrence radiographic classification of osteoarthritis *(16)*. Regarding this classification, no radiological sign of osteoarthritis was classified as grade 0, doubted narrowing of joint space and possible osteophytic lipping was grade 1, definite narrowing and ostophytic formation was grade 2, moderate multiple osteophytic formation, sclerosis and possible deformity was grade 3 and large osteophytes, marked narrowing, severe sclerosis and definite deformity was grade 4.

The IBM Statistical Package for Social Sciences (SPSS) 20.0 was used for all ststistical analysis. Distributions of the variables were evaluated by Kolmogorov-Smirnov test. The difference between the ages was compared by independent t-test. The difference between sex distributions was evaluated by Fisher-Exact test. Statistical significance was calculated as $p < 0.05$.

RESULTS

The mean age of the patients were 38,8 (range, 20-60), the mean follow up time was 56 months (range 13-120 months). Demographical features of the patients are given in Table I.

The mean range of motion (ROM) at latest follow-up in affected knees was 117° (range, 80°-130°). (Table 2) Regarding Kellgren & Lawrence radiographic classification of osteoarthritis in affected knees; 15 patients (39,4%) was grade 0, 6 (15,8%) were grade 1, 10 (26,3%) were grade 2, 4 (10,6%) were grade 3 and 3 (7,9%) were grade 4. (Figure 2)

The mean KSS Knee Score of the patients at latest follow-up were 87,26 (range, 44-100), mean KSS Functional Score was 90 (range, 50-100) and mean HSS score was 91,1 (range, 53-100).

Just 7 patients showed insecurity at the single leg hoop test. (Table II)

The mean absolute angular standard deviation in 60° at passive motion of the operated knee was 60° while unaffected knee was 70°. The mean absolute angular standard deviation in 30° at passive motion of both sides was found 60°. However, the mean absolute angular standard deviation in 60° at active motion of the operated knee was 130° while unaffected knee was 110°. As the same measurements applied at 30° the operated side was found 80° and unaffected side was found 70°. (Table III and IV)

There was no significant difference between the mean absolute angular standard deviation in 60° at passive motion of the operated and unaffected knees. ($p = 0,22$) There was also no significant change in active motion between two sides. ($p = 0,22$) The same patient groups also did not show significant difference in 300 at passive and active motion between two sides. ($p = 0,47$, $p = 0,62$)

Regarding age groups (20-29, 30-39, 40-49, 50-59) there were no significant difference in proprioception change between the operated and unaffected knees.($p = 0,52$, $p = 0,17$, $p = 0,23$, $p = 0,26$)

The total number of high energy trauma pattern, that is, Schatzker type V and VI (AO/OTA 41-C2/C3) tibia plateau fractures in the study was 10 (26,3%) cases (5-type V (C2), 5-type VI (C3)). There was no significant difference in proprioception change between the two groups. ($p = 0,30$, $p = 0,40$, $p = 0,85$, $p = 0,77$)

DISCUSSION

Proprioception of the knee joint composed of afferent signals of proprioceptive receptors in the knee and other organs (eg. proprioceptive receptors of vestibular organs, visual system, other organs) *(15,13)*. Proprioception is expected to alter following tibia plateau fractures due to either impaired muscular or tendinous tissue balance or arthritic changes *(13,27,14)*.

Hurley et al. have identified the relation between the joint injury and neuromuscular control. They have stated that an abnormal afferent data following a joint injury can reduce the excitability of α-motor neurons and the voluntary quadriceps activation. In cases of severe joint injury, extensive reduction in activation can prevent achieving threshold values to stimulate muscle hypertrophy, thus delays

Table I. — Demographic features of the cases

Number of the patients	Age	Mechanism of injury	Schatzker Classification	AO/OTA Classification	Applied surgical method	Follow up (months)
1	50	Fall from height	Type I	41-B1	Lateral plate	39
2	42	Direct injury	Type III	41-B2	Lateral plate	53
3	35	Motor vehicle accident	Type II	41-B3	Lateral plate	39
4	41	Direct injury	Type V	41-C2	Medial and Lateral plate	42
5	37	Fall from height	Type VI	41-C3	Medial and Lateral plate	52
6	41	Fall from height	Type II	41-B3	Lateral plate	39
7	53	Fall from height	Type VI	41-C3	Medial and Lateral plate	15
8	31	Motor vehicle accident	Type IV	41-B3	Medial and Lateral plate	15
9	43	Direct injury	Type I	41-B1	Lateral plate	21
10	53	Fall from height	Type VI	41-C3	Medial and Lateral plate	51
11	29	Direct injury	Type I	41-B1	Lateral plate	45
12	47	Motor vehicle accident	Type II	41-B3	Lateral plate	38
13	25	Direct injury	Type I	41-B1	Lateral plate	58
14	39	Direct injury	Type II	41-B3	Cannulated screw	92
15	22	Direct injury	Type II	41-B3	Lateral plate	15
16	44	Fall from height	Type V	41-C2	Medial and Lateral plate	120
17	60	Direct injury	Type II	41-B3	Cannulated screw	47
18	50	Direct injury	Type IV	41-B3	Medial plate and Lateral screw	20
19	50	Direct injury	Type VI	41-C3	Medial and Lateral plate	95
20	33	Direct injury	Type IV	41-B3	Cannulated screw	50
21	35	Motor vehicle accident	Type IV	41-B3	Medial and Lateral plate	13
22	39	Direct injury	Type V	41-C2	Medial and Lateral plate	83
23	52	Direct injury	Type V	41-C2	Medial and Lateral plate	49
24	20	Direct injury	Type II	41-B3	Lateral plate	66
25	22	Direct injury	Type IV	41-B3	Cannulated screw	90
26	41	Direct injury	Type II	41-B3	Cannulated screw	111
27	34	Direct injury	Type II	41-B3	Cannulated screw	71
28	37	Direct injury	Type II	41-B3	Lateral plate	54
29	37	Motor vehicle accident	Type VI	41-C3	Medial and Lateral plate	91
30	41	Fall from height	Type V	41-C2	Lateral plate and Cannulated screw	24
31	42	Direct injury	Type II	41-B3	Cannulated screw	15
32	51	Direct injury	Type IV	41-B3	Medial plate and Lateral screw	80
33	24	Fall from height	Type IV	41-B3	Medial plate	13
34	31	Motor vehicle accident	Type II	41-B3	Cannulated screw	108
35	23	Motor vehicle accident	Type I	41-B1	Lateral plate	106
36	54	Direct injury	Type II	41-B3	Lateral plate	79
37	38	Direct injury	Type II	41-B3	Lateral plate	50
38	29	Fall from height	Type II	41-B3	Lateral plate	63

rehabilitation. Abnormal afferent data generated in joint line can affect γ-motor neuron excitability thus proprioception. Rehabilitation increases excitability of α- and γ-motor neurons and improves proprioception *(14)*. This relation forms the basis of our hypothesis. None of the patients in our study were included in a special physiotherapy and rehabilitation program, but only muscular

Fig. 2. — Preoperative radiographic views, CT and postoperative radiographic views of a case from our series.

Fig. 2A. — Anteroposterior and lateral preoperative radiographic view of a 37 year old case, classified as 43-C3 regarding AO/OTA classification

Fig. 2C. — Anteroposterior and lateral postoperative radiographic views at 3rd year following operation have shown no sign of malunion.

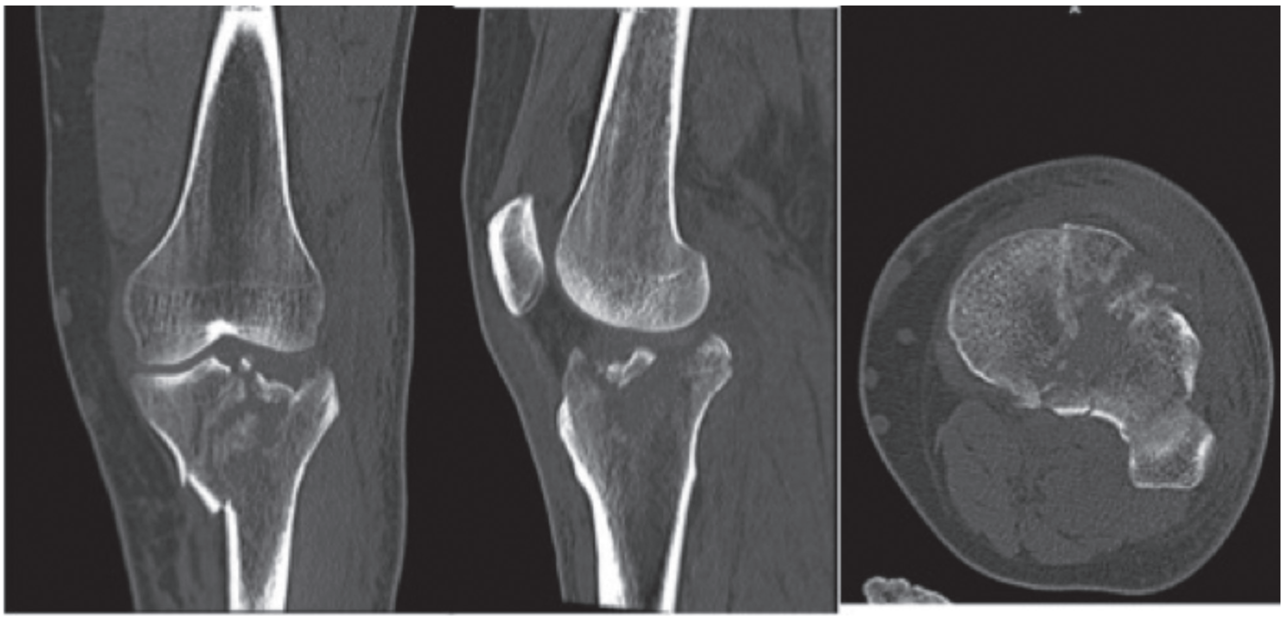

Fig. 2B. — CT series have demonstrated a comminuted intraarticular fracture affecting ACL and PCL attachment on tibia

Table II. — The muscle strength in flexion and extension, the final range of motion in both knees and single leg hoop test performed in the affected knee

Case Number	Affected knee muscle strength in flexion	Affected knee muscle strength in extension	Affected knee Single Leg Hoop Test	Final Range of Motion in Affected Knee (degrees)	Uaffected knee muscle strength in flexion	Unaffected knee muscle strength in extension	Final Range of Motion in Unaffected Knee (degrees)
1	5/5	5/5	Safe	130	5/5	5/5	130
2	5/5	5/5	Safe	120	5/5	5/5	120
3	5/5	5/5	Safe	120	5/5	5/5	120
4	5/5	4/5	Insecure	110	5/5	5/5	130
5	5/5	5/5	Safe	115	5/5	5/5	120
6	5/5	5/5	Safe	120	5/5	5/5	140
7	4/5	5/5	Insecure	105	5/5	5/5	130
8	5/5	5/5	Insecure	115	5/5	5/5	130
9	5/5	5/5	Safe	125	5/5	5/5	125
10	4/5	5/5	Insecure	100	5/5	5/5	125
11	5/5	5/5	Safe	120	5/5	5/5	120
12	5/5	5/5	Safe	115	5/5	5/5	130
13	5/5	5/5	Safe	130	5/5	5/5	130
14	5/5	5/5	Safe	130	5/5	5/5	130
15	5/5	5/5	Safe	130	5/5	5/5	130
16	4/5	5/5	Insecure	85	5/5	5/5	130
17	5/5	5/5	Safe	110	5/5	5/5	125
18	5/5	5/5	Safe	130	5/5	5/5	130
19	4/5	4/5	Insecure	80	5/5	5/5	120
20	5/5	5/5	Safe	100	5/5	5/5	130
21	5/5	5/5	Safe	120	5/5	5/5	120
22	5/5	5/5	Safe	130	5/5	5/5	130
23	4/5	4/5	Insecure	80	5/5	5/5	130
24	5/5	5/5	Safe	130	5/5	5/5	130
25	5/5	5/5	Safe	130	5/5	5/5	130
26	5/5	5/5	Safe	120	5/5	5/5	120
27	5/5	5/5	Safe	130	5/5	5/5	130
28	5/5	5/5	Safe	120	5/5	5/5	120
29	5/5	5/5	Safe	130	5/5	5/5	130
30	5/5	5/5	Safe	110	5/5	5/5	130
31	5/5	5/5	Safe	130	5/5	5/5	130
32	5/5	5/5	Safe	130	5/5	5/5	130
33	5/5	5/5	Safe	110	5/5	5/5	120
34	5/5	5/5	Safe	100	5/5	5/5	130
35	5/5	5/5	Safe	130	5/5	5/5	130
36	5/5	5/5	Safe	120	5/5	5/5	130
37	5/5	5/5	Safe	120	5/5	5/5	130
38	5/5	5/5	Safe	120	5/5	5/5	120

Table III. — Absolute angular standard deviation of the cases

Patient Number	Unaffected site Passive 60°	Operated site Passive 60°	Unaffected site Passive 30°	Operated site Passive 30°	Unaffected site Active 60°	Operated site Active 60°	Unaffected site Active 30°	Operated site Active 30°
1	5	5	2	3	12	9	1	2
2	0	19	25	11	7	6	0	11
3	5	9	10	5	2	1	7	4
4	7	11	16	3	22	14	5	3
5	6	5	13	7	6	3	3	3
6	2	3	2	5	6	6	16	23
7	2	6	7	7	7	11	3	7
8	10	9	5	12	8	5	14	4
9	5	29	4	17	9	20	6	14
10	6	8	8	8	15	14	2	11
11	6	15	11	9	2	5	1	11
12	3	2,0	6	6	4	7	5	11,0
13	2	3	8	2	0	0	1	7
14	11	13	2	5	7	8	15	9
15	5	10	0	8	19	13	5	8
16	4	16	2	3	6	9	4	0
17	13	2,7	7	6	11	13,30	10	13
18	19	5	8	5	38	19	25	23
19	2	3,0	1	4	8	17,0	5	10,0
20	6	7	0	11	14	27	4	8
21	5	7	1	4	9	5	9	8
22	2	3,7	3	3	19	33,3	3	1,7
23	4	0	1	6,0	14	24,0	17	13
24	1	10,0	5	0	19	14,0	10	7,0
25	10	5	1	1	14	22	1	2
26	3	3	5	7	4	12,7	8	10
27	8	4,0	10	1,0	2	18,0	7	3,0
28	18	11	4	3,2	18	11,3	10	8,3
29	5	5,0	4	3,0	15	13,0	3	4,0
30	6	3	1	16	3	6	5	3
31	6	4,0	1	5,0	10	17,0	17	12,0
32	4	4	21	17	18	9	18	10
33	5	17	21	3	19	25	4	3
34	1	1	3	8	12	7	2	22
35	7	1	10	5	9	11	5	2
36	3	12	6	13	9	21	3	15
37	1	1	2	2	6	9	11	5
38	2	8	7	0	3	17	14	1

Table IV. — Mean absolute angular standard deviation values

Unaffected site Passive 60°	Operated site Passive 60°	Unaffected site Passive 30°	Operated site Passive 30°	Unaffected site Active 60°	Operated site Active 60°	Unaffected site Active 30°	Operated site Active 30°
6°	7°	6°	6°	11°	13°	7°	8°

strengthening and ROM exercises were described if necessary, during hospitalization and/or follow-up.

Proprioception has been evaluated in ACL injuries in many articles. Barret has evaluated the relation between proprioception with functional results and patient satisfaction after ACL reconstruction surgery and showed that proprioception is an major factor for the outcome *(3)*. We believe that proprioception is an important factor for functional recovery of the knee. Impairment of the proprioception can cause knee insecurity similar to ACL injury, although just 7 patients showed knee insecurity with single leg Hoop test in comparison to their unaffected site. Surgical management of the tibia plateau fractures includes internal or external fixation, hybrid fixation and arthroscopy-assisted interventions *(20,7)*. All cases in our study applied ORIF by various techniques (eg. single/double incisions, unilateral and/or bilateral plate fixation, screw only) and the joint line was anatomically restored as far as possible. The mean KSS knee score was found 87,3 at last follow-up of the patients.

Various studies on factors that affect joint proprioception have been reported in the literature. Fatigue, immobilization, disuse, trauma, surgical intervention, ligamentous laxity, aging and arthritis were blamed factors *(9)*. From these factors, we only evaluated surgical interventions, age, and trauma in our study. We believed that trauma and alteration of the soft tissues after the surgical procedures could have affected the proprioception, although the results did not support our hypothesis.

Tibia plateau fracture patients can possibly represent with one or more of these conditions. From this point of view it is estimated that proprioception can be affected in a surgically managed tibia plateau fracture patient at each step, from the mechanism of trauma to surgical exposure.

Gaston et al. in a study, which they have evaluated regaining of normal knee functions following tibia plateau fractures, have concluded that only 14% of the patients regain normal quadriceps strength within first year postoperatively. The authors have also reported that only 30% of the cases achieve normal hamstring strength within first year postoperatively *(11)*. The same study have deducted that the mean regaining time of functions was considerably longer in older age groups. Our study, at this point of view, have indicated no difference in proprioception between the two sides as the quadriceps and hamstring strength at both knees showed no difference at mean 56 weeks follow-up time. Regarding age groups and proprioception relation; there were no significant difference .

Various methods have been proposed to evaluate the proprioceptive sensitivity of the knee joint in sagittal plane. The literature includes two groups of study mostly. First group of studies include the evaluation of (re)positioning sense. These tests require the evaluation of active and/or passive motion of the knee joint at a certain angle and the knee is repositioned after several seconds. Patients are then asked to mimic the percept angle in the same knee and/or the opposite knee and/or on knee model. Second group of studies are related with sensation in passive and slow motion of the knee joint (motion sense tests and threshold determination tests). Patients are expected to percept initiation and finalization of the motion as quickly as possible. Sometimes the patients are also expected to define the examined knee side. This test intends to evaluate slowly adapting Ruffini or Golgi mechanoreceptors, but giving less information about muscle receptors. Thus, this group of test is commonly preferred in ligament pathologies *(18,29,19,2,24)*. Our proprioception measurement method as indicated previously, was active or passive repositioning, which is a validated method *(6)*.

Various studies have indicated that the knee joint has different proprioception values at different angles *(21,10)*. Erden et al. have reported that the angular standard deviation value increases from 15° to 60°, reaches to its maximum value in 600 and decreases at 90°. We have evaluated proprioception in two different angles (30° and 60°). We have detected no significant difference in standard deviation threshold between two angles.

The effect of structures forming the knee joint on proprioception was also indicated on patellofemoral problems. Sanchis-Alfonso et al. have indicated that peripatellar plexus does not work properly due to patellar malalignment in chronic patellofemoral pain syndrome and this condition can be evaluated by proprioceptive tests *(25)*. Histopathologic evaluation has also indicated nerve injuries in peripatellar soft tissues and partially lateral retinaculum. Authors have reported that varying proprioceptive sensation may result in patellar instability related with patellar pain.

We can also suggest that trauma can cause a similar effect around the tibiofemoral joint even tough it does not always affect the tissue around the patella.

Barret et al. have shown that perception of knee position is impaired with age and in osteoarthritic knees *(4)*. Besides, proprioceptive disorders in gonarthrosis patients may be a cause of knee pain or activity limitation *(5)*. Regarding development of osteoarthritis, 3 of our cases (7,9%) were classified as grade IV-severe osteoarthritis. The mean age of these cases were 48,6. Our study have also evaluated the patients regarding age (< 40, > 40) however no significant difference was detected between two groups by means of change in proprioception.

Limitations of our study include; limited number of cases, preoperative measurement of the knee score was technically impossible, thus the pre- and postoperative muscle strength could not be compared and the timing of the proprioception measurement was relatively long after surgery. To measure pre- and postoperative muscle strength; the unaffected side should be better studied postoperatively, thus a comparison can be possible. The timing of proprioception could be done in annual follow-up to conclude better resultsOur data and follow-up time fort he patients were limited to make a better conclusion for long term results. Further studies with large cohort groups and early proprioception measurements after surgery can be done.

CONCLUSION

Impairment in components of proprioception sense in intra-articular fractures like tibia plateau fractures is expected. However our study has indicated that the proprioception measured by the continuous passive movement (CPM) mode of the isokinetic dynamometer (HUMAC® NORMTM Testing & Rehabilitation System, USA), at the operated extremity is not significantly different from the unaffected knee in tibia plateau fractures at long-term follow-up. However, preoperative (unaffected side) or early postoperative (both side) measurements could allow a better comparison and understanding to this problem.

As far as we know there is limited number of studies in the literature that indicates the relation between proprioception and knee joint by means of fracture. Our study more likely may reflect our hypothesis instead of stating a decision..

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