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The Evaluation Of Tibial Torsion Angle After Anterior Cruciate Ligament Reconstruction*

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Abstract

The aim of this study is to investigate the effect of anterior cruciate ligament (ACL) reconstruction on tibial torsion angle (TTA) in the operated limb using computed tomography (CT) and physical examination methods and to show the relationship between post-operative muscle strength features and TTA by using isokinetic dynamometer. 21 patients between 18 and 36 years old (25.4±6.8) who underwent ACL reconstruction with hamstring tendon (HT) autograft and then completed the ACL rehabilitation were included in this study. Isokinetic strength measurements were evaluated by Biodex-Multi Joint System-Pro 4 dynamometer. To evaluate TTA; CT, transmalleolar and thigh-foot angle (TFA) measurements were carried out. There was no significant TTA differences between 21 operated and non-operated knees for any method (p> 0.05). At the isokinetic evaluation to the extension direction there were a significant differences 60-180º/sec in peak torque value (p=0,0001, p=0,003) and average power value (p=0,004, p=0,002). As the percentage of losses in peak torque value to the flexion direction at velocity of 180 º/sec increases, the CT diagnosed angle difference between both knees increases. (p<0,01, r=0,548) As the percentage of losses in average power value to the extension direction at the velocity of 60 º/sec increases, the TFA difference between both knees increases. (p<0,01, r=0,563) . The isokinetic evaluation findings show that the strength loss between the knees increases the TTA differences. This finding shows the relationship of post-op rehabilitation with TTA varies and re-injury risk. In the isokinetic evaluation, subjects with high loss of strength in the direction of flexion at 180º/sec velocity had higher TTA differences, so rehabilitation protocols should be also focused on muscle endurance.

Keywords: Anterior Cruciate Ligament, Tibial Torsion, Muscle Strength Dynamometer

INTRODUCTION

Although anterior cruciate ligament (ACL) injuries may occur with traumas encountered in daily life, they occur mostly in the form of sports injuries (%91).(1) The most widely used autograft for ACL reconstruction is hamstring tendon (HT) autograft, followed by bone-tendon-bone autograft.(2-4) HT autograft is a commonly used graft for ACL reconstruction due to its accessibility and ease of harvesting, soft tissue tunnel passage, comparable strength to natural ACL, and some positive benefits such as a specific personalized graft length and diameter.(3, 4)

One of the important intrinsic risk factors for ACL injuries is lower extremity alignment problems.(5-8) Dynamic valgus and torsional alignment stresses are modifiable risk factors for ACL tears and re-injuries and they can be affected by muscle fatigue and strength imbalance.(5, 7) Because of the important role of limb muscle imbalance in alignment problems and associated ACL tear or re-injury risk, strength and proprioceptive exercises are integrated into many professional training prevention programs.(5, 9, 10). Tibial torsion is one of these important alignment problems for ACL injuries and also is the most important reason for in-toeing.(7, 8, 11)

What is rotation, what is torsion?

The difference between tibial torsion and rotation for the first time was emphasized by Rosen and Sandick in 1955.(12) Rotational bone issues within the normal values (±2 standard deviations of the mean) range are termed rotational variations and those outside the normal range are referred to as torsional deformities.(11) Torsion angle is defined as the rotational deformity of the long bones and it occurs as a result of long bones turning longitidunally around their own axes.(13-15). The 'tibial torsion angle' (TTA) is the angle between the axis passing through the tibial condyles and the axis passing through the malleols in the ankle also called 'transmalleolar angle' (TMA).(11, 15-18)

How to evaluate TTA?

Tibial torsion was first described by Le Damany in 1903 and then in 1909, Le Damany accepted the patella-tuberositas tibia and malleols as reference points and made anthropometric measurements with the "BROCA" device and obtained an average value of 23.7°.(19) Staheli and Engel described the method of measurement 'tibiofibular torsion' evaluation using a trigonometric method in 1972.(13) In 1976 Ritter et al. and in 1979 Malekafzali and Wood have published their own TTA measurement techniques with goniometer-adapted devices.(20, 21) Turner and Smillie in 1981, they reported "JIG device method" for TMA measurement.(22) Staheli et al. have described the measurement of TMA by physical goniometric assesments for the first time such as thigh-foot angle (TFA) and angle of the transmalleolar axis in 1985.(11) Hazlewood et al. in 2007 identified the 'footprint method'and compared it with TMA measurement methods.(23)

TTA was first measured in 1955 by Rosen and Sandick using a radiographic method.(12) Computed tomography (CT) scanning was used by Jakob et al. for the evaluation of TTA and it was compared with the physical assesment methods of TTA measurements in 1980.(24) In 1987, Joseph et al. performed ultrasonography (USG) for the first time for tibial torsion measurement.(25) The magnetic resonance imaging (MRI) technique was used in 1997 by Schneider et al. for the measurement of TMA.(26)

CT is the most reliable method for tibial torsion measurements, as it is the gold standard in bone imaging and easy to identify reference points.(22, 24, 27). A difference of more than 2 degrees between both extremities in CT and TMA evaluation is considered abnormal.(22, 24) A difference of more than 1 degree between both extremities in TFA evaluation is considered abnormal.(5, 13, 24). A gap has been observed in the area of investigation of the effect of ACL reconstructions on TTA. The aim of this study is to investigate the effect of ACL reconstruction on TTA in the operated knee and to show the relation of post-op. rehabilitation with TTA by isokinetic system.

MATERIAL AND METHODS

22 volunteers between 18 and 36 years old (25.4±6.8) who underwent ACL reconstruction with HT autograft and then completed the ACL rehabilitation were included in this study. One volunteer was excluded because of femoral anteversion diagnosed. All patients received the same postoperative protocol at the same institute. All of the ACL injuries occurred while doing sports. Surgery reports of all of subjects were examined before they were included in the study. 9 of the 21 subjects were included in the study at 6-9 months of post-op, 7 at 15-18 months and 5 at 18-21 months. (Table 1)

Inclusion criteria:

• Male gender, aged between 18-36,

• The operation was performed with HT autograft,

• The subject has completed the 6th month of post-op. rehabilitation and Lysholm score must be over 90 points.

Exclusion criteria:

• ACL re-injury and/or revision surgery,

• Any meniscus tear, cartilage lesions, medial-lateral ligament sprain and ruptures or repair on the operated and the other extremity,

• Any torsional problem such as femoral anteversion and/or metatarsus adductus, which may affect TTA in the operated and other extremity.

The knees of the patients were evaluated with the 'Lysholm' knee score. Detailed lower extremity physical examination including rotational profile evaluation of both limbs were performed. Both knees laxity were compared by KT-1000 (Med-metric, San Diego, California) arthrometer. Both knee joints isokinetic strength of extensor/flexor muscle groups measurements were evaluated with Biodex-Multi Joint System-Pro 4 (Biodex Medical Systems Inc, Shirley, NY, USA) dynamometer. In the isokinetic evaluation, the loss and gain values of Peak Torque (Newton.meter) and Average Power (Watt) in flexor and extensor muscle groups at 60 °/sec (5 reps) and 180 °/sec (10 reps) values were recorded.

To measure TTA, physical examination methods TMA and TFA (Figure 1) evaluations were used. CT (Lightspeed 16, GE Medical Systems, Milwaukee, Wisconsin, USA), one of the imaging methods, was also used for measurement and CT based TTA (Figure 2) was evaluated by the same highly-experienced radiologist.

Ethical approval was obtained from the faculty's ethical committee (334/14.09.2010). Written informed consent was obtained from all patients and a separate informed consent form was also signed for CT scanning. The procedure was performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Statistics

Wilcoxon test was used to evaluate TTA between the operated and non-operated knee differences. Paired t test was used to evaluate isokinetic differences. The relationship between TTA differences and the isokinetic dynamometer test results (percentage of loss) was examined using Spearman correlation.

RESULTS

TTA evaluation

In the CT evaluation, the number of subjects with a difference of more than 2 degrees between the two sequences was 13 (%61,9) (Table 2). In the TMA evaluation, the number of subjects with a difference of more than 2 degrees between the two extremities was 15 (Table 3) (%71,4). In the TFA evaluation, the number of subjects with a difference of more than 1 degree between the two extremities was 12 (%57,1) (Table 4).

There was no significant difference between 21 operated knees and 21 non-operated knees for any method ($p > 0.05$). (Table 5)

Isokinetic evaluation (Table 6)

The Peak Torque (Newton.meter)

- There was a significant difference in 60º/sec extension between operated knee and normal knee values ($p<0,001$).
- There was a significant difference in 180º/sec extension between operated knee and normal knee values ($p<0,01$).

The Average Power (Watt)

- There was a significant difference in 60º/sec extension between operated knee and normal knee values ($p<0,01$).
- There was a significant difference in 180º/sec extension between operated knee and normal knee values ($p<0,01$).

The relationship between the Isokinetic values and TTA

In the relationship between the percentage of losses in Peak Torque value and the TTA differences between the operated knee and the non-operated knee:

- As the power loss at extension at velocity of 60º/sec increases, the TMA difference between both knees increases. ($p<0,05$, $r=0,507$)
- As the power loss at extension at velocity of 60º/sec increases, the TFA difference between both knees increases. ($p<0,05$, $r=0,525$)
- As the power loss at extension at velocity of 60º/sec increases, the CT diagnosed angle difference between both knees increases. ($p<0,05$, $r=0,526$)
- As the power loss at flexion at velocity of 180º/sec increases, the CT diagnosed angle difference between both knees increases. ($p<0,01$, $r=0,548$)

- As the power loss at flexion at velocity of 180º/sec increases, the TMA difference between both knees increases. (p<0,05, r=0,454)

In the relationship between the percentage of losses in Average Power value and the TTA differences between the operated knee and the non-operated knee:

- As the power loss at extension at velocity of 60º/sec increases, the TMA difference between both knees increases. (p<0,05, r=0,436)
- As the power loss at extension at velocity of 60º/sec increases, the TFA difference between both knees increases. (p<0,01, r=0,563)
- As the power loss at flexion at velocity of 60º/sec increases, the TMA difference between both knees increases. (p<0,05, r=0,455)
- As the power loss at flexion at velocity of 60º/sec increases, the TFA difference between both knees increases. (p<0,05, r=0,488)
- As the power loss at flexion at velocity of 180º/sec increases, the TMA difference between both knees increases. (p<0,05, r=0,435)
- As the power loss at flexion at velocity of 180º/sec increases, the TFA difference between both knees increases. (p<0,05, r=0,438)

DISCUSSION

ACL injuries are often non-contact injuries and occur mostly in the form of sports injuries.(1) Recently the techniques performed with HT autograft for ACL tear have been preferred more because of reasons such as less post-operative anterior knee pain complaints and range of motion (ROM) restriction, strength to natural ACL, safer in young patients whose epiphyses are not completely closed and minimal loss of quadriceps muscle strength.(2-4)

Lower extremity alignment problems such as increased femoral anteversion and TTA are one of the most important intrinsic risk factors for ACL injuries and re-injuries.(6, 7) Dynamic valgus and torsional alignment differences are modifiable risk factors for ACL tears/re-injuries and they can be affected by muscle fatigue and limb strength imbalance.(5-8). In particular, the studies of Shelbourne et al. were highly effective in the development and acceleration of ACL rehabilitation. According to these studies, the period of return to sports after ACL repairs and rehabilitation is given as 5-6 months unless there is any complication.(10) Because of the important role of limb muscle imbalance in dynamic alignment problems, intensive strength and proprioceptive training exercises are integrated into these accelerated programs in time.(5, 9, 10)

There was no significant difference in the flexion at isokinetic measurements between the both knees of the each subjects in the peak torque and average power values in this study. However, statistically significant differences were found at all speeds in the direction of extension. This finding was in line with the literature information that after ACL reconstruction, quadriceps muscle strength decreased more than hamstring muscles independent of the graft type.(4, 9, 28) According to these studies, it was stated that the primary priority in rehabilitation should be given to this muscle group since quadriceps are stabilizing muscles.(4, 5, 9)

The method that is accepted as the gold standard in the measurement of TTA is CT.(11, 24, 27, 29) In this study, TFA and TMA, which are among the physical examination methods, were preferred due to their ease of measurement and compatibility with each other and CT.(11, 14) Although the methods described in the clinical examination are practically useful, they can lead to different results among the people who perform the measurement.(29) In addition, various TTA evaluation studies have values close to those in all evaluation methods of this research.(11, 13, 14, 17) In this study, there was no significant difference between 21 operated knees and 21 non-operated knees for any method (p> 0.05). In most of the patients between 6-9 months post-op, the TTA differences between the two knees was found abnormal. (Table 3,4,5) Although there were differences in all three angle measurements in this group, there was no statistically significant difference due to the low number of patients.

There is a gap in the area of investigation of the effect of ACL reconstructions on TTA However, statistically significant correlations were found between the angles mentioned by the isokinetic evaluation, which is a good indicator of the outcome of the rehabilitation process. In the isokinetic system, tests performed at 60º/sec velocity are more effective in measuring maximal strength, while tests at 180º/sec are more effective in measuring muscle endurance. In the isokinetic evaluation of this study, as the losses in both peak torque and average power increased, the differences in TTA increased. As the losses both peak torque and average power in 60º/sec (both at the quadriceps and hamstring muscle groups) increased, the differences in TTA increased. As the losses both peak torque and average power in 180º/sec (only at the hamstring muscle groups) increased, the differences in TTA increased. In some systematic review and meta-analysis studies, it was found that the risk of ACL re-injury is higher for the athlete with low muscle endurance.(1, 30-32) When our correlation finding and the literature information about low muscle endurances association with re-injury are combined, it can be said that putting weight on strength exercises (low weight and abundant repetition) in the direction of the hamstring muscle group may reduce the risk of ACL re-injury. In 2011, Clare et al. in their meta-analysis study, they argued that the rate of return to sport should be questioned below fifty percent regardless of the duration of post-op rehabilitation period in elite sports and that the criteria for return to the sport should be reviewed and the tibial rotation evaluation being a criterion.(30) Despite the fact that all of the subjects were selected as post-op patients after the 6th month in accordance with the current protocol and all of these patients received post-op rehabilitation, the determination of these values suggests that the rehabilitation processes and protocols should be questioned. In the meta-analysis study involving 5770 patients from 47 studies examining return to sports in athletes after ACL repairs by Arden et al. although an average of 90% of the patients achieved good results in basic laxity and strength tests and 85% of the patients received good ratings at knee scoring tests, only 63% were able to reach the pre-injury activity level, and only an average of 44%

returned to sports.(30) Arden et al. Afterwards, with the study they updated, they stated that the criteria of return to sports for all sports injuries should be questioned and they proposed a 5-question model.(33) In the discussion section of the their 2011 study, it was emphasized that the results of ACL repair and rehabilitation were exaggerated and the criteria used for return to sports focused on anterior instability, and tibial rotation measurements were skipped and tibial rotation measurements could be an emphasis for return to sports.(30)

THE MAIN POINTS

Accelerated rehabilitation protocols, time to return to sport, and criterias are still controversial to reduce the risk of re-injury. Although it was found that the ACL operations did not change the TTA statistically, the fact that this angle difference varies between the operated knee and normal knee in a great majority of patients in post-op 6-9 months suggests that this angle difference may be related to the rehabilitation period.

The high loss in strength differences increases the TTA differences between the knees. This finding shows the relationship and importance of post-op rehabilitation with TTA.

In the isokinetic evaluation, subjects with high loss of strength in the direction of flexion at 180º/sec velocity have higher TTA differences.

In the rehabilitation protocols, besides the maximal strength, especially in the direction of flexion, strength training should be focused on endurance.

There is no conflict of interest with Authers and financial support for study, so financial confilct.

Tables & Figures

Table 1: Grouping the post-operative period by months

Post-op (month)	N	Percentage (%)
6-9	9	**42,9**
15-18	7	**33,3**
18-21	5	**23,8**
Total	21	**100**

Table 2: Grouping CT angles according to post-op period

Post-op (month)	CT angle-no difference N Percentage (%)	CT angle differences >2º N Percentage (%)	Total N Percentage (%)
6-9	2 %22,2	7 %77,8	**9** **%100**
15-18	3 %42,9	4 %57,1	**7** **%100**
18-21	3 %60	2 %40	**5** **%100**
Total	8 %38,1	13 %61,9	**21** **%100**

Table 3: Grouping TMA according to post-op period

Post-op (month)	TMA-no difference N Percentage (%)	TMA differences >2º N Percentage (%)	Total N Percentage (%)
6-9	1 %11,1	8 %88,9	**9** **%100**
15-18	3 %42,9	4 %57,1	**7** **%100**
18-21	2 %40	3 %60	**5** **%100**
Total	6 %28,6	15 %71,4	**21** **%100**

Table 4: Grouping TFA according to post-op period

Post-op (month)	TFA-no difference N Percentage (%)	TFA differences >2º N Percentage (%)	Total N Percentage (%)
6-9	3 %33,3	6 %66,7	**9** **%100**
15-18	3 %42,9	4 %57,1	**7** **%100**
18-21	3 %60	2 %40	**5** **%100**
Total	9 %38,1	12 %61,9	**21** **%100**

Table 5: Evaluation of TTA differences

Methods	Mean±SD	P value
CT (operated)	37,1±6,1	
CT (normal)	37,1±7,5	**1**
TMA (operated)	23,1±5,3	
TMA (normal)	21,6±5,3	**0,391**
TFA (operated)	10,7±3,2	
TFA (normal)	10,1±3,3	**0,148**

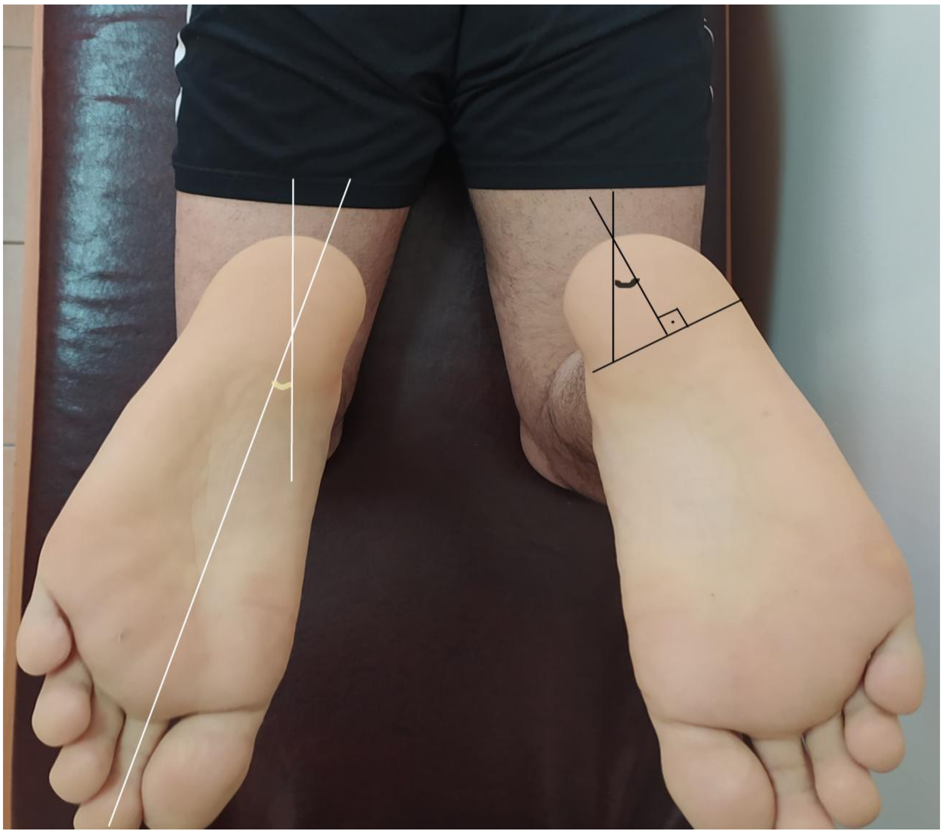

Figure 1. Left limb: TFA, Right limb: TMA evaluation.

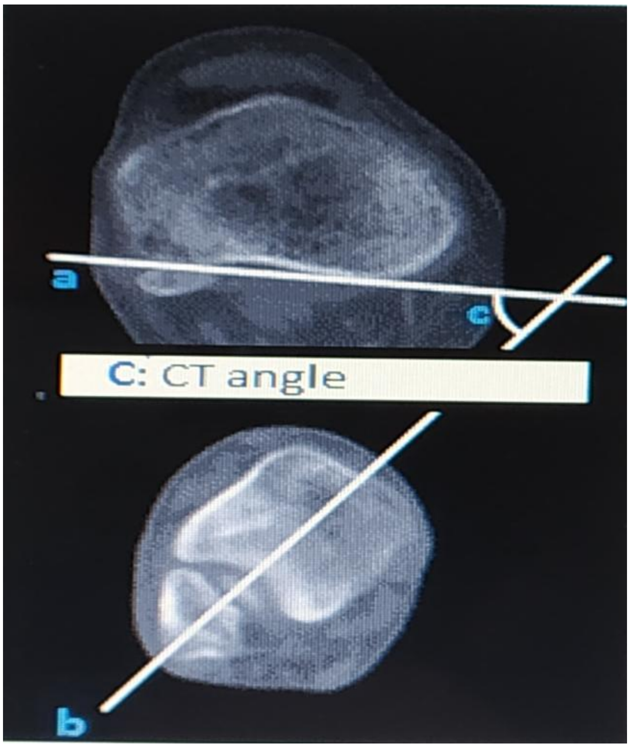

Figure 2. a: Tibial Proximal Transverse Axis, **b:** Lateral Malleolar Axis, **c:** CT-based angle.

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