ORIGINAL ARTICLE

**Morphometric Analysis and Blood Supply of Gracilis and Semitendinosus Tendons; Their Clinical Importance in Anterior Cruciate Ligament Reconstruction**

WAGIH GAMAL ELDIN ELBARRANY, WARDAH ABDULLAH ALASMARI, FARIS MOHAMED ALTAF

**ABSTRACT**

**Aim:** To analyze morphometric measurements of anterior cruciate ligament, gracilis and semitendinosus tendons and the blood supply of gracilis and semitendinosus tendons with its clinical importance.

**Methods:** Sixteen preserved human cadaveric legs were used after lead oxide injection into the external iliac artery. The tendons gracilis and semitendinosus muscle were dissected carefully to measure their lengths, diameters and cross-sectional area and to identify their arterial blood supply.

**Results:** The mean length, diameter and cross-sectional area of anterior cruciate ligament were $4.1 \pm 0.03$ cm, $6.2 \pm 0.04$ mm and $30.6 \text{ mm}^2$; those of gracilis tendon were $18.9 \pm 0.71$ cm, $6.3 \pm 0.17$ mm and $30 \pm 0.18$ mm$^2$ respectively while those of semitendinosus tendon were $25 \pm 0.06$ cm, $7 \pm 0.12$ mm and $3038.9 \pm 0.23$ mm$^2$ respectively. Each tendon has a longitudinal artery from the lower pedicle of the muscle; that received tributaries from the regional arteries through fascial bands. These vessels anastomosed with the periosteal branches of the upper part of the medial surface of the tibia.

**Conclusion:** Anterior Cruciate Ligament reconstruction, maintaining the insertion of the gracilis and semitendinosus tendons can help to preserve their blood supply with consequent expected better prognosis.

**Keywords:** Anterior Cruciate Ligament (ACL), Gracilis-Semitendinosus, Morphometric Analysis, Reconstruction.

**INTRODUCTION**

The rupturing of the anterior cruciate ligament (ACL) is a common sport injury that necessitates reconstruction for the patient to return to previous physical activities. Semitendinosus gracilis graft (STG) surgery remains the most common type of anterior cruciate ligament reconstruction together with the bone–tendon–bone (BTB) graft$^{1,2}$. While much of the reports signify better knee stability with a BTB graft; others reported no significant differences between BTB and STG graft$^{3-5}$. Many orthopedic surgeons prefer the quadrupled autologous semitendinosus-gracilis graft and consider it as their first choice, since it has powerful material strength and it does not affect the quadriceps extensor mechanism$^6$. Moreover, it has excellent results similar to bone-patellar tendon-bone procedure if they are compared$^{7,8}$. As a result of the sacrifice of these tendons, the expected weakness of knee flexion and internal rotation of the knee are compensated by other hamstring muscles (semimembranosus and biceps femoris muscles)$^9$. Post-operative follow-up of the anterior cruciate ligament reconstruction procedures revealed that, some patients suffer post-operative pain and knee instability. The possible contributing factor for such reported failure could be attributed to re-vascularization process, and hence it can strengthen the graft. Combined grailis-semitendinosus tendons allograft results in good functional recovery in reconstruction of neglected patellar tendon rupture, if the insertion is preserved$^{10}$. Re-vascularization of the reconstructed ACL starts from the periphery of the graft and increased towards its center. The graft strength and intensity usually can predict its damage or neo-vascularization together with matrix synthesis$^{11,12}$. Using MRI, the uniform low signal intensity of the normal ACL was reported in the reconstructed ACL after 1 year of reconstruction, which is attributed to the graft vascularity$^{13}$. Thus, the aim of study is to analyze some morphometric measurements of semitendinosus and gracilis tendons and description of their blood supply, in order to achieve an effective clinical importance for the reconstructive surgeries of the ACL.

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MATERIAL AND METHODS

The research work was approved by the Ethical Committee Board of the Faculty of Medicine, Umm Al-Qura University, Makkah, Kingdom Saudi Arabia. Design: Morphometric analysis and blood supply of gracilis and semitendinosus tendons were studied in the preserved human cadaveric legs after injecting through the external iliac artery with lead oxide.

Patients/Participants: This study included 16 preserved human cadaveric legs.

Settings: The insertion of the gracilis and semitendinosus muscles into the medial surface of the upper end of the tibia was done with great care. The tendon of each muscle was dissected to study the mode of insertion, accessory bands, and its blood supply. The complete length (using metallic ruler), diameter (using Vernier Swiss Caliber with 0.05 accuracy), and cross-sectional areas (using the computerized image analyzing system with preserving the original magnification) of gracilis and semitendinosus tendons were measured. The insertion of each muscle and the number of tendinous and fascial bands were described. The arterial pedicles supplying each tendon were identified, and their sources were studied. The mean and standard deviations of the obtained values were measured and compared. T-test was also used for significant variation between the measurements of the two tendons, and those of the ACL.

RESULTS

The mean of total lengths, diameters and cross-sectional areas of anterior cruciate ligament, gracilis and semitendinosus (Table I).

The mean diameter of gracilis tendon was significantly larger than ACL diameter; p<0.033. The ACL mean cross-sectional area was significantly larger than that of gracilis; p<0.0001. The gracilis muscle and the semitendinosus muscle were inserted in a common tendon into the medial part of the upper surface of the tibia. The length of the fusion area was at an average of 2± 0.3 cm (ranging from 1.5 to 2.6 cm) (Fig.1.A). The site of the common insertion into the tibia had a mean length of 2 ± 0.05 cm, ranging from 1.8 to 3 cm. The insertion of the Gracilis tendon was attached to the deep fascia on the medial side of the knee by a fascial band, and the blood vessels supplying it were communicating with a vascular plexus over the tibial tuberosity and ligamentum patellae (Fig.1.B). The tendon was attached to the deep fascia on the tibia by another fascial band, which further merged the tendons of the semitendinosus muscle carrying extensive anastomosed vessels with the tibial periosteal branches (Fig.1.B). Proximal to these bands; there were small two fascial bands connecting it to tendons of gracilis and semitendinosus. Gracilis tendon was covered by a fascial sheath, in between its layers, there were blood vessels that ran to supply it (Fig.1.C). Gracilis tendon divided into two tendinous slips in all the studied cases, one inserted into the tibia & other is inserted into the tendon of the semitendinosus muscle (Fig.1.D & Fig.2.A). In all of the studied cases, there was an axial artery that originated from the blood vessels of the fleshy part and ran along the tendon. It received minor pedicles through the fascial bands that connected the tendon to the surrounding. The fibrous bands, attached to the semitendinosus tendon and to the periosteum of the tibia carried the main and abundant anastomosis between the tendon vasculature and the periosteal branches to the tibia (Figs.2.B & 3.A).

The mean diameter of semitendinosus tendon was significantly larger that of ACL; p<0.0001, while it's cross-sectional area was at was significantly larger than that of ACL; p<0.0001 (Table I). The semitendinosus tendon was attached to the deep fascia of the leg that covered the medial head of the gastrocnemius muscle through a large triangular aponeurotic band. It carried the major vascular anastomosis between the vessels supplying the tendon and the periosteal branches to the tibia. The saphenous nerve and the saphenous artery lie superficial to this fascia (Fig.3.A). It was also attached to the tendon of gracilis through small fibrous bands that were ranged from 1 to 3 with the average of 2 bands. These bands contained vascular branches between the two tendons. There was an axial blood vessel that passed along the tendon in all cadavers dissected. The axial blood vessel communicated with the feeding blood vessels that were carried through the fascial bands (Fig.3.B & 2.B). The tendon was attached by a fascial band that carried arterial pedicles from the popliteal artery (Fig.3.C). It also got arterial pedicles from the periosteal blood vessels of the tibia that were the major vascular supply to the tendon (Fig.3.D).

Table I. It shows the lengths, diameters and cross-sectional areas of ACL, gracilis and Semitendinosus.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ACL</th>
<th>Gracilis</th>
<th>Semitendinosus</th>
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<tr>
<td>Tendon length</td>
<td>4.1±0.03cm (range 2.5 to 5.4)</td>
<td>18.9±0.71cm (range 11.2 to 25.4)</td>
<td>28±0.06 cm (range 17 to 30)</td>
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<tr>
<td>Diameter</td>
<td>6.2±0.04 mm (range 4.8 to 7.7)</td>
<td>6.3±0.17mm (range 4.5 to 7.2)</td>
<td>7±0.12 mm (range 5 to 9.4)</td>
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<tr>
<td>Cross section area</td>
<td>30.7±0.23mm² (range 25 to 38.2)</td>
<td>30±0.18 mm² (range 24.2 to 33.0)</td>
<td>38.9±0.23mm² (range 30 to 42)</td>
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Fig. 1: Fig.1A. The insertion of the semitendinosus (Se) and gracilis (Gr) tendons into the tibia. Gracilis tendon (Gr) is attached to the deep fascia by fascial band, (black arrows) containing blood vessels (BV) to communicate with a vascular plexus over the tibial tuberosity and ligamentum patellae (L) (arrow head). Tendon semitendinosus muscle (white arrows) lies deep to the gracilis tendon. Fascia over the medial side of the knee (F), Sm; semimembranosus muscle. Fig.1B. The insertion of the gracilis tendon (Gr) is attached by a fascial band (me) to the deep fascia on the medial side of the knee and to the deep fascia (F) on the tibia (T) by another band that merges with the semitendinosus muscle (Se). Fig.1C The blood vessels (arrow head) supplying the Gracilis tendon lie between layers of its fascial sheath (arrow). Fig.1.D. Gracilis tendon (Gr) gives two tendinous slips (arrows), one inserted into the tibia & other is inserted into the tendon of the semitendinosus muscle (Se). MG; medial head of gastrocnemius.

Fig. 2: Fig.2A. It shows the lines of insertion of tendons (a,b) of semitendinosus (ST) and gracilis (G) respectively; (dotted line c) is the length of tendon fusion. Ap; aponeurosis, GAS; lateral head of gastrocnemius. Fig.2B. It shows a diagrammatic illustration of the blood supply to gracilis and semitendinosus tendons. A longitudinal artery (a) connected with arterial pedicles (f) through the fascial bands (mesotendons) (e) and to blood vessels (c) lying between the tendon (h) and its sheath (b).
DISCUSSION

Anterior cruciate ligament is crucial in preventing anterior displacement of the tibia, in stabilizing against excessive internal rotation together with the valgus and varus stresses, in protecting the cartilages and menisci injuries\(^{14,15}\). The grafted hamstring tendon is subjected to different biological processes after ACL reconstruction including; avascular necrosis, revascularization, cellular proliferation, and matrix remodeling\(^{16}\). Previous studies have showed that, the remodeling of tendon grafts used for anterior cruciate ligament reconstruction (ACLR) is essential for better clinical outcome after ACLR. Since tendon grafts are separated from their vascular supply during harvesting, ingrowth of new blood vessels is an essential step for the graft remodeling. The vascular endothelial growth factor (VEGF) is reported to be the most potent known angiogenic factor in tendons grafts neo-vascularization. It is involved in its remodeling at the early phase after ACL reconstruction by promoting angiogenesis together with reduction of the stiffness of the ACL graft. It also results in the increased knee laxity at least twelve weeks after ACL reconstruction. Lack of vascularity within the ACL graft may be predisposed to degeneration or micro-ruptures during the post-operative period. Therefore, revascularization of the grafted tendon, in addition to the tendon-bone interface, is crucial for establishing a successful outcome following ACL reconstruction surgery\(^{16-18}\).

The present study showed that the blood supply to the gracilis and semitendinosus tendons comes from different sources. Longitudinal blood vessels that ran on the outer surface of the tendons originated from the arterial pedicles to the fleshy part of the muscle. It anastomosed with blood vessels that run between the tendon and its covering sheath, which originated from the regional blood vessels such as; the popliteal artery or the saphenous artery, and reached the tendon through the fascial bands or the mesotendons. The blood vessels for these tendons also anastomosed with the periosteal blood vessels, which lie on the tibia near the site of insertion of the tendons. There were many connecting fibrous bands between the two tendons that carried anatomizing blood vessels. In order to keep the tendons insertion into the tibia intact during elevation of the tendons for ACL reconstruction surgery, distally based tendon graft keep the blood supply to the transposed tendons. Consequently, ACL graft might not suffer
ischemia or necrosis as it happens in traditional ACL reconstruction grafts.\textsuperscript{11,12}

Using magnetic resonance imaging (MRI) with a contrast agent such as gadolinium diethylenetriamine penta-acetic acid (Gd-DTPA) can measure the intensity of the graft that can reflect and predict its vascularity. It was reported that revascularization of the graft starts from the periphery towards its center. It could be concluded that revascularization starts from the periosteal blood vessels. After ACL reconstruction, the graft showed different intensities when examined by MRI, which could demonstrate its partial degeneration. These changes in the graft intensity might indicate its degenerative damage, and also the degree of revascularization together with matrix synthesis within the graft.\textsuperscript{11,12,19,20} Therefore, such degenerative changes could explain persistence of pain and knee instability in some patients after reconstruction, which could be attributed to failure of re-vascularization with consequent partial graft necrosis. The preservation of the attachment of the distal end of semitendinosus and gracilis tendons showed great success in reconstruction of neglected patellar ligament injury.\textsuperscript{11} It also gives a long term accepted recovery and success with tolerability to valgus and varus stresses with protection of the menisci.\textsuperscript{15,21} It is simply due to preservation of the vascularity and strength of the graft.

Normal ACL graft should have low signal intensity on short-TE sequences. An intermediate signal is often seen within grafts from approximately 4-8 months after reconstruction, decreasing with time and usually completely resolving by 12 months. The increased signal at this period is thought to be due to graft re-vascularization and synovialization. Authors suggested that, a normal graft tendon should resume a uniform normal low-signal-intensity MR imaging appearance after 1 year. Tendon graft intensity changes during MRI examination might reflect not only graft damage, but also neo-vascularization and matrix synthesis within the graft.\textsuperscript{11,12,19} ACL graft intensity was more strongly associated with clinical knee instability. Post-operatively, it was reported that six to twelve months often represented a poorly functioning knee. Assessment of the ACL graft has been shown between MRI findings and physical examination of anterior and rotational instability.\textsuperscript{19} The gradient echo T2*WI sequence is likely to fill the gap between MRI findings and clinical knee instability of physical examination.\textsuperscript{22}

Disturbance in the blood supply to the grafted tendons during harvesting them for ACL reconstruction can induce ischemia. Consequently, it can destroy the receptors, possibly causing knee stability as a result of disturbance of reflex arcs.\textsuperscript{23,24}

On leaving the insertion of the gracilis and semitendinosus tendons intact, it can help to preserve these mechanoreceptors. This may result in a better stability of the knee after ACL reconstruction, and can direct the attention of better modification of post-operative rehabilitation protocols.

**CONCLUSION**

The tendons of gracilis and semitendinosus muscle have parameters which is suitable for ACL reconstruction. Maintaining the insertion of the gracilis and semitendinosus tendons during ACL reconstruction can help to preserve the blood supply of their tendons with consequent expected less complications and better clinical outcome.

**Conflict of interest:** The research holds no conflict of interest and is funded by the deanship of scientific research and Islamic Culture, Umm Al-Qura University, Makkah, Saudi Arabia.

**REFERENCES**


