

Anatomical and Morphometric observations of Gracilis Muscle and its Vascular Pedicles; A Cadaver Study

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Abstract: The Gracilis muscle anatomy has been documented by some authors, statistical and observations data has been described, but it need re-explored for many metrical and non-metrical parameters, so the purpose of this study was to explore the morphological, parameters, topography and identify the vascular pedicles of Gracilis muscle including their number, caliber, and their locations. Also the whole length of Gracilis muscle in relation to the length of the lower limb and gender. The study was conducted on 46 preserved formalin fixed adult human cadaveric lower limbs (26 left and 20 right), The Gracilis muscle was exposed, dissected and studied regarding its origin, insertion, parameters and the number and points of entry of the supplying neurovascular pedicles and diameters of arteries just before entry to the Gracilis muscle. Gracilis muscle mean of total length, fleshy part length, overlap length, tendon length were 46.73 ± 3.91 , 21.29 ± 3.57 , 11.63 ± 3.45 and 13.82 ± 1.52 cm respectively. The mean width of Gracilis fleshy part: near origin, at middle and before overlap part were 3.38 ± 0.61 , 2.66 ± 0.48 , 1.82 ± 0.43 cm respectively. Gracilis muscle thickness mean of fleshy and tendentious parts were 0.69 ± 0.18 , 0.29 ± 0.04 cm respectively. The number of neurovascular pedicles entering to Gracilis were 1 to 3, accompanied by two-venacommittant. The main artery diameter mean was 0.17 ± 0.03 cm. The nerve supply to Gracilis muscle entered with the main proximal vascular pedicle or near it. There is statistically difference only at FP width at middle in the left lower limb. There were highly correlation between FP width at middle, FP width before tendon and total length of lower limb. The present study concluded that anatomical and morphometric analysis of the Gracilis muscle reveals variation in different individuals as well as in different gender and this must be considered in reconstructive and plastic surgery.

Key Words: Gracilis, Morphometric, Cadaver, Vascular Pedicles,

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I. Introduction

The Gracilis muscle is the most superficial adductor muscles on the medial side of the thigh. It arises by a thin aponeurosis from the medial margins of the lower half of the body of the pubis, the whole of the inferior pubic ramus, and the adjoining part of the ischial ramus. The muscle's fibers run vertically downward, ending in a rounded tendon. This tendon passes behind the medial condyle of the femur curves around the medial condyle of tibia where it becomes flattened, and inserts into the upper part of the medial surface of the body of the tibia, below the condyle. At its insertion, the tendon situated immediately above that of the semitendinosus muscle, and the tendon of the Sartorius muscle, which it joins to form the pesanserinus, overlaps its upper edge. A few of the fibers of the lower part of the tendon prolonged into the deep fascia of the leg [1]. The anterior division of obturator nerve innervates it and its blood supply enters via its lateral surface. The main pedicle arises from the branch of the profunda femoris artery, and enters at the junction of the upper and middle thirds of the muscle. The Gracilis musculocutaneous flap based on this pedicle. A less important artery enters the distal third of the muscle from the femoral artery. There is a minor proximal supply from the medial circumflex femoral artery [1,2].

Gracilis muscle used in reconstructive plastic surgery, mainly in setting of tendon grafting and muscle transplantation. Gracilis tendon grafts used in repair of anterior cruciate ligament of knee joint. It has also been used for a wide variety of procedures including lip augmentation, facial palsy management, breast reconstruction, , anorectal and urethral fistula. In graciloplasty, gracilis muscle with its nerve supply has been

used for faecal incontinence repair [2]. It has advantage of easy accessibility and minimum donor site morbidity [3,4].

The success of muscle flaps in reconstructive surgery based on a reliable blood supply. The circulation of a muscle based on the major vascular pedicles that enter the muscle belly. When the muscle has more than one vascular pedicle, the relative importance of each vascular pedicle concerning a muscle is necessary to be evaluated. When division of a pedicle generally results in muscle avascular necrosis or if the external diameter of this pedicle is more than 0.8 mm, this pedicle defined as a major or dominant pedicle [5].

The aim of the present work is to study and identify the vascular pedicles to gracilis muscle including their number as well as their locations. In addition, the whole dimensions of Gracilis muscle in relation to the length of the thigh.

II. Material and Methods

The study used 46 formalin fixed adult human cadaveric lower limbs (26 left and 20 right), at the Department of Human Anatomy, Faculty of Medicine, Umm Al Qura University, Makkah- Saudi Arabia. The lower extremities disarticulated and were stored in a formalin tanks. The lower limbs dissected, Gracilis fascia removed, and specimens have to be checked that they had no surgery or congenital deformities involving the area under study. The length of each lower limb (from antero- superior iliac spine to lateral malleolus) measured. Gracilis muscle was exposed and dissected to identify its neurovascular bundles. The total length of Gracilis muscle was estimated from the middle of its origin from the body of the pubic bone, the inferior pubic ramus and the adjoining part of the ischial ramus till its insertion in the medial surface of the tibia.

The following measurements were taken from the Gracilis origin: a. The point of entry of each of the vascular pedicles to Gracilis. b. The point of entry of the nerve supply to Gracilis. The belly as well the overlapping parts length were measured. The length of the tendon of the Gracilis muscle measured from the end of the overlapping part until its insertion into the supero-medial surface of the tibia (Figure 3). These measurements performed by using a measuring tape. Linear measurements of Gracilis belly width near origin, at middle and before overlap part, Gracilis fleshy thickness (Figure 3), Gracilis tendon thickness and distance of tendon insertion from anterior tibial border, were done by using Vernier caliper (General Tools Mfg. Co. LLC New York, NK 10013). The neurovascular pedicles entering into the Gracilis muscle (Fig. 4) counted in each lower limb and their diameters measured by using vernier caliper (General Tools Mfg. Co. LLC New York, NK 10013).

Three authors performed each of the measurements. The average of the three measurements obtained and tabulated for the data analysis.

STATISTICAL ANALYSIS:

For all statistical analyses, the SPSS statistical software version 15 used. The ANOVA and person chi square tests used and P. values of 0.05 or less regarded as statistically significant.

ETHICAL APPROVAL:

The study was approved by the biomedical ethics committee, Faculty of Medicine, Umm Al-Qura University- Makkah, Saudi Arabia.

III. Results

Table 1. Presented that; the mean of lower limbs length was 89.78 ± 5.92 cm. Gracilis muscle mean of total length, fleshy part length, overlap length, tendon length parameters were 46.73 ± 3.91 , 21.29 ± 3.57 , 11.63 ± 3.45 and 13.82 ± 1.52 cm respectively

The mean width of Gracilis fleshy part linear measurement: near origin, at middle and before overlap part were 3.38 ± 0.61 , 2.66 ± 0.48 , 1.82 ± 0.43 cm respectively. Gracilis muscle thickness mean of fleshy and tendinous parts were 0.69 ± 0.18 , 0.29 ± 0.04 cm respectively. Insertion of Gracilis muscle by tendon, into the upper part of the medial surface of the tibia. The mean distance of tendon insertion from anterior tibial border was 1.96 ± 0.64 cm.

The correlation between FP length, Overlap length, Tendon length, FP thickness, tendon thickness, FP width near origin, FP width at middle, FP width before tendon and the side of Gracilis muscle / Gender. ($P > 0.05$). In this study, there is significant statistically difference only at FP width at middle in the left side. These were represented in **Tables 2, 3, 4, 5.**

Table 6 showed that: In Gracilis muscle, there were highly correlation ($P > 0.01$) between FP width at middle, FP width before tendon and total length of lower limb. There was correlation between total Gracilis length and total length of lower limb.

The neurovascular pedicles number entering into the Gracilis muscle were ranging between 1 to 3 and represented in **Fig. 1.** The distance of the entry of the main neurovascular pedicle to the Gracilis muscle from its

origin was ranging between 5.5 to 11.2 cm; some pedicles enter until 29.1 cm (all before overlapping part of the Gracilis muscle). The frequency of range of distance of the main neurovascular pedicles from the origin of Gracilis muscle was represented in **Fig. 2**. It was observed that the neurovascular pedicles were highest(69.57%) at the range of 5.0 -10.0 cm away from the origin of the Gracilis muscle.

The diameter of the neurovascular pedicle at their entrance into the Gracilis muscle was ranging between 0.05 and 0.2cm and the main pedicles diameter mean was 0.17 ± 0.03 cm, it is accompanying by two veins.

Observations: The gracilis muscle tendon expanded to deep fascia of the leg, semitendinosus and Sartorius muscles and innervated by anterior division of the obturator nerve in all studied specimens. Regarding the nerve supply of the muscle, in 91.3% of the cases, the muscle received one branch that entered the muscle.

Table 1: Morphometric statistics of Gracilis muscle

Parameters	Mean	STD	Minimum	Maximum
Lower limbs length	89.778	5.9234	79.9	99.1
Gracilis muscles length	46.726	3.9140	40.70	55.60
Gracilis fleshy length	21.278	3.5657	14.30	29.60
Gracilis overlap length	11.626	3.4530	6.80	20.30
Gracilis tendon length	13.822	1.5223	10.40	16.60
Gracilis fleshy width near origin	3.0783	0.6060	1.80	4.30
Gracilis fleshy width at middle	2.6565	0.4794	1.60	3.50
Gracilis fleshy width before overlap part	1.8217	0.4282	1.00	2.60
Gracilis fleshy thickness	0.6870	0.1779	0.40	0.95
Gracilis tendon thickness	0.2935	0.0434	0.20	0.35
Distance of main pedicle from Gracilis origin	9.4739	3.5167	5.50	11.50
Distance of tendon insertion from anterior tibial border	1.9565	0.6416	0.70	3.20

Table 2: The parameters of the fleshy, overlapping and tendentious parts of Gracilis muscle in left side, both genders and their significance

	female	male	significance
FP length	21.467±4.760	4.455 ±22.114	0.805
Overlap length	10.883±2.567	4.443±12.857	0.359
Tendon length	13.633±0.903	2.257 ±13.857	0.825
FP thickness	0.196± 0.683	3.160± 1.843	0.392
Tendon thickness	0.041 ± 0.275	0.053± 0.307	0.259
FP width near origin	0.825±2.800	0.553 ± 3.171	0.354
FP width at middle	0.525 ± 2.300	0.385 ± 2.914	0.033
FP width before tendon	0.479 ± 1.525	0.250± 1.957	0.061

Table 3: The parameters of the fleshy, overlapping and tendentious parts of Gracilis muscle in right side, both genders and their significance

	Female	male	Significance
FP length	2.491±20.920	1.686±20.240	0.627
Overlap length	3.623 ±11.240	11.996 ±2.587	0.714
Tendon length	1.445±14.320	13.500± 1.225	0.361
FP thickness	0.195±0.740	0.640 ±0.185	0.430
Tendon thickness	0.042±0.260	0.300 ±0.035	0.141
FP width near origin	3.280± 0.638	3.080 ±0.349	0.556
FP width at middle	2.660± 0.555	2.720 ±0.277	0.834
FP width before tendon	1.710±0.553	2.100 ±0.212	0.179

Table 4: The parameters of the fleshy, overlapping and tendentious parts of Gracilis muscle in female, right and left sides and their significance

	Right	left	Significance
FP length	2.491 ±20.920	4.760 ±21.467	0.823
Overlap length	3.623 ±11.240	2.567±10.883	0.853
Tendon length	1.445 ± 14.320	0.903 ±13.633	0.360
FP thickness	0.195 ± 0.740	0.197 ± 0.683	0.644
Tendon thickness	0.042 ± 0.260	0.042 ± 0.275	0.568
FP width near origin	0.638 ±3.280	0.825 ± 2.800	0.317
FP width at middle	0.555 ±2.660	0.525 ±2.300	0.298
FP width before tendon	0.553±1.710	0.479 ± 1.525	0.566

Table 5: The parameters of the fleshy, overlapping and tendentious parts of Gracilis muscle in male, right and left sides and their significance

	right	left	Significance
FP length	1.686 ± 0.240	4.455 ± 22.114	0.396
Overlap length	2.587 ± 11.996	4.443 ± 12.857	0.708
Tendon length	1.225 ± 13.500	2.257 ± 13.857	0.756
FP thickness	0.185 ± 0.640	3.160 ± 1.843	0.421
Tendon thickness	0.035 ± 0.300	0.053 ± 0.307	0.801
FP width near origin	0.349 ± 3.080	0.553 ± 3.171	0.753
FP width at middle	0.277 ± 2.720	0.385 ± 2.914	0.360
FP width before tendon	0.212 ± 2.100	0.251 ± 1.957	0.326

Table 6: The significance of difference between the total length of the lower limb and different parameters of the Gracilis muscle.

	FP length	Overlap length	Tendon length	FP thickness	Tendon thickness	FP width near origin	FP width at middle	FP width before Tendon	Total gracilis length
Lower limbs length	0.330	0.149	0.665	0.656	0.530	0.185	0.000	0.001	0.014

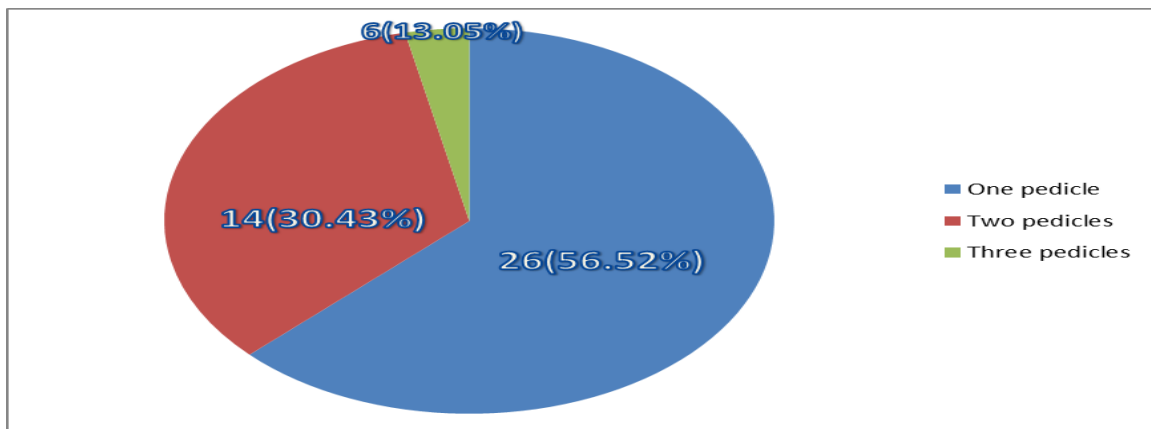


Figure 1: Frequency of the neurovascular pedicles number entering the Gracilis muscle (n=46).

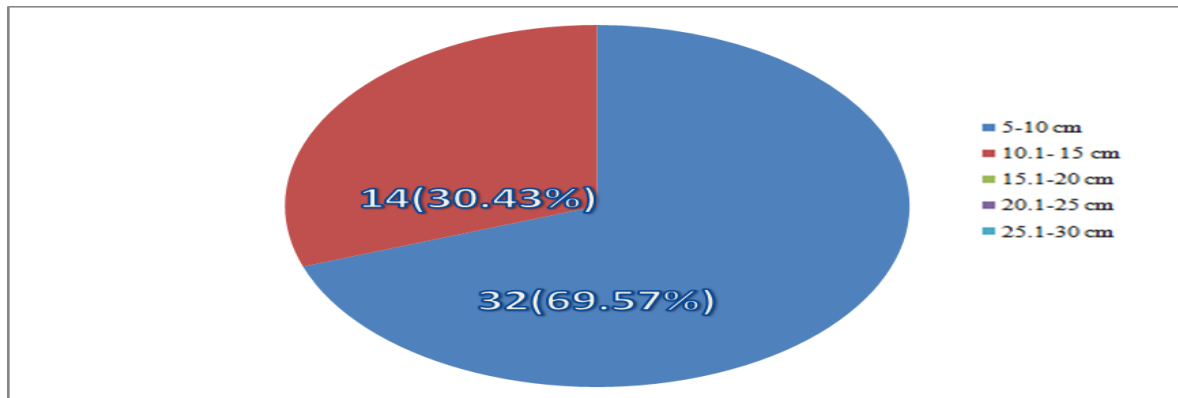


Figure 2: Frequency of distance of the main neurovascular pedicles entering into the Gracilis muscle from its origin.



Fig. 3. Measurements performed in the present study: Gracilis fleshy length (A-blue), Gracilis overlap length (B-red), Gracilis tendon length (C-yellow), Gracilis fleshy width near origin (D-green), Gracilis fleshy width at middle (E-green), Gracilis fleshy width before overlap part (F-green).



Figure 4: One main neurovascular pedicles entering into the Gracilis muscle. It's nerve (N). The main artery (A) accompanying by two veins.

IV. Discussion

Gracilis muscle is widely used in reconstructive surgery. Previously, there is anatomical and radiological studies concerning the Gracilis muscle parameters and its neurovascular pedicles, however although there is variation in findings [6,7,8]. Major previous studies for Gracilis muscle parameters focusing on the length of the tendinous part and few of them mentioned belly part parameter.

Dziedzic DW et al [9], during their study on human Gracilis muscles, observed that there is part of Gracilis muscle where the tendinous and belly parts overlapping. They call this part as internal part of the distal tendon, where in our study, we mentioned it as the overlapping part of the Gracilis muscle and we measured it as a separate part.

The present study reveals that, the mean of Gracilis muscle total length, fleshy part length, overlap length, tendon length were 46.73 ± 3.91 , 21.28 ± 3.57 , 11.63 ± 3.45 and 13.82 ± 1.52 cm respectively. These findings are partial similar to the data mentioned by Dziedzic DW et al [9], in which Gracilis muscle mean of total length, tendon length were 48.2 and 13.9 cm, while it differs in belly part and overlapping part length 34.3 and 15.5 cm. We believe that this difference due to divergence in way of measurement. In general the parameters of Gracilis muscle differ from individual to other and in different sexes and population [6,7,8]. These factors are important in reconstructive surgery and graft.

The present study shows that: Gracilis muscle thickness mean of tendinous parts was 0.29 ± 0.04 cm (range 0.2-0.35) cm after removal of its covering fascia, while Elbarrany WG et al. [10] preserved its covering sheath and the diameter was 0.63 ± 0.17 cm (range 4.52-7.2).

The Gracilis muscle belly was used for analsphincter repair [11], repair of ano-vaginal or recto-vaginal fistulas [6,12,13], reconstruction of upper and lower limbs and breast reconstruction. [7,14,15]. Literature review showed, few previous studies concerning the width and the thickness of the Gracilis muscle fleshy part. The mean width of Gracilis fleshy part near origin, at middle and before overlap part were 3.38 ± 0.61 , 2.66 ± 0.48 , 1.82 ± 0.43 cm respectively. Gracilis muscle thickness mean of fleshy part was 0.69 ± 0.18 cm. Dziedzic DW et al. [9] and Rajeshwari MS, Roshankumar BN [16] only mentioned the wide for the gracilis muscle belly at its proximal end as 3.19 and 3.9 cm respectively. These finding maybe helpful in future for surgery in grafts or analsphincter repair in human.

The Gracilis muscle tendon expanded before its final insertion to deep fascia of the leg, semitendinosus and Sartorius muscle to form Pesanserinus. This finding is similar to previous studies [9,17]. The mean distance of tendon insertion from anterior tibial border was 1.96 ± 0.64 cm.

In plastic and reconstructive surgery, the neurovascular pedicles of the gracilis muscle are of major significance. The loss of function after muscle transposition is minimal besides, it provides a highly vascular tissue, which is beneficial for healing of tissues. The proximally based gracilis muscle and musculocutaneous flaps provide cover for a wide range of tissue defects (6,18). This study showed that the number of neurovascular pedicles entering into the Gracilis muscle were ranging between 1- 3, 56.52% had one pedicle, 30.43% had two and 13.05% for three neurovascular pedicles. The distance of the entry of the main neurovascular pedicle to the Gracilis muscle from its origin was ranging between 5.5 to 11.2 cm. It observed that the neurovascular pedicles were highest (69.57%) at the range of 5.0–10.0 cm away from the origin of the Gracilis muscle. These findings were approximately the same as what observed by Rajeshwari MS, Roshankumar BN [16], and Vigato E et.al. [6] in which they mentioned that the number were between 1-5 (majority 1-3) and the main pedicle enter the muscle at its proximal part (10.5 ± 2 cm). The diameter of the neurovascular pedicle at their entrance into the Gracilis muscle was ranging between 0.05 and 0.2 cm and the main pedicles diameter were 0.2 cm, it is accompanying by two veins. Vigato E et.al. [6] mentioned that, the mean diameter of the vascular pedicle was 0.25 cm, just before its entrance into the Gracilis muscle, probably due to the in-vivo method. Gracilis muscle innervation by the anterior division of the obturator nerve, as it is mentioned in all literature.

Limitlaohaphan C et al. and Chiang et al. [19, 20], discernment that the leg length can be used to foretell the graft length. Since the graft length is proportional to the height of the person, it is suitable to prepare the graft with respect to the height of the person. The radiological investigations like computed tomography and nuclear magnetic resonance can be used to predict the length and diameter of the grafts, before the surgical procedure [21,22]. The present study revealed that: there were correlation between total length of Gracilis muscle, FP width at middle, FP width before tendon and the total length of the lower limb.

The correlation between FP length, Overlap length, Tendon length, FP thickness, tendon thickness, FP width near origin, FP width at middle, FP width before tendon and the side of Gracilis muscle or Gender. In this study, there is significant statistically difference only for FP width at middle in the left side.

Tuman et al [23], found that, Gracilis tendons in males had a larger cross-section than those in females and significant correlations between the length of the femur and the length of both tendons were only found in females. Thus, height can be used as a predictive factor for the length of tendons in women only, but the reasons for these gender differences remain unclear.

There is no evidence in the literature correlating the parameters of Gracilis muscle and its side. Vadgaonkar R et.al [24] mentioned no significance statistics comparing the length of semitendinosus muscle belly and its tendon over the right and left sides.

This study may be useful and give preoperative information about the feature of the Gracilis muscle and patient counseling for surgeons. However, there are several anatomical issues which must be taken into account when performing Gracilis muscle graft harvesting in order to prevent intraoperative as well as post-operative complications. The present study concluded that; anatomical and morphometric analysis of the Gracilis muscle reveals variation in different individuals as well as in different gender, and it remains a popular graft for many reconstructive procedures, including anterior cruciate ligament reconstruction and others reconstructive plastic surgery.

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