Anatomical Variations of the Saphenous and Descending Genicular Artery Perforators: Cadaveric Study and Clinical Implications for Vascular Flaps

Kanit Sananpanich, M.D.
Pichitchai Atthakomol, M.D.
Sirichai Luevitoonvechkij, M.D.
Jirachart Kraisarin, M.D.

Chiang Mai, Thailand

Background: With increasing use of free vascular flaps of the saphenous artery and descending genicular artery, the authors investigated the anatomical variations in cadavers.

Methods: Thirty-one fresh cadaveric thighs were studied by anatomical dissection. The perforators and their source arteries were skeletonized along their courses to the superficial femoral artery and measured. The perforators' nomenclature and abbreviations were modified from the Gent consensus. The skin and bone perforators were evaluated for their role in skin, bone, and osteocutaneous flaps.

Results: The descending genicular artery was noted in 27 thighs (87 percent) and gave rise to at least one skin perforator that could be used to develop an osteocutaneous flap. The chimeric pedicle length increased and the chimeric arm length decreased, as the descending genicular artery skin perforators were more distally located. The saphenous artery was noted in all 31 thighs, and in 16 (52 percent) it originated from the superficial femoral artery. Most musculocutaneous perforators of the saphenous artery were associated with the sartorius, whereas those of the descending genicular artery were associated with the vastus medialis. Superficial femoral artery skin perforators were noted in 10 thighs (32 percent). Two clinical cases, illustrating the use of the descending genicular artery vastus medialis perforator flap and of the distal-direct perforator osteocutaneous flap, are reported.

Conclusions: This study investigated the anatomical variations in the skin and bone perforators of the medial knee. Free skin or bone flaps were achieved in all specimens and osteocutaneous chimera flaps were achieved in 87 percent of the thighs. (*Plast. Reconstr. Surg.* 131: 363e, 2013.)

Free vascular flaps of the descending genicular artery have been used increasingly over the past three decades. The original description of the descending genicular artery flap was first presented in 1981 as the saphenous artery flap by Acland et al.,[1] because the latter arises from the former. The authors advocated this flap as a free tissue transfer because it has a long vascular pedicle with a large arterial caliber, thin minimally hirsute skin, straightforward dissection, and a distinct nerve supply for sensate flaps. The vascular pedicle of the saphenous flap includes the saphenous artery and the accompanying saphenous nerve. However, the saphenous artery may also arise more proximally from the superficial femoral artery[2] (Fig. 1). Other vascular skin flaps of the medial knee area were described later using the more distal branches of the descending genicular artery.[3–5] The osteoarticular branch of the descending genicular artery, which supplies the medial femoral condyle, has been used increasingly for bone nonunion.[6–12] The combination of skin and bone vascular branches in a single vascular

From the Department of Orthopedics, Chiang Mai University.
Received for publication August 21, 2012; accepted September 10, 2012.

DOI: 10.1097/PRS.0b013e31827c7067

Disclosure: *The authors have no financial interests to declare in relation to the content of this article.*

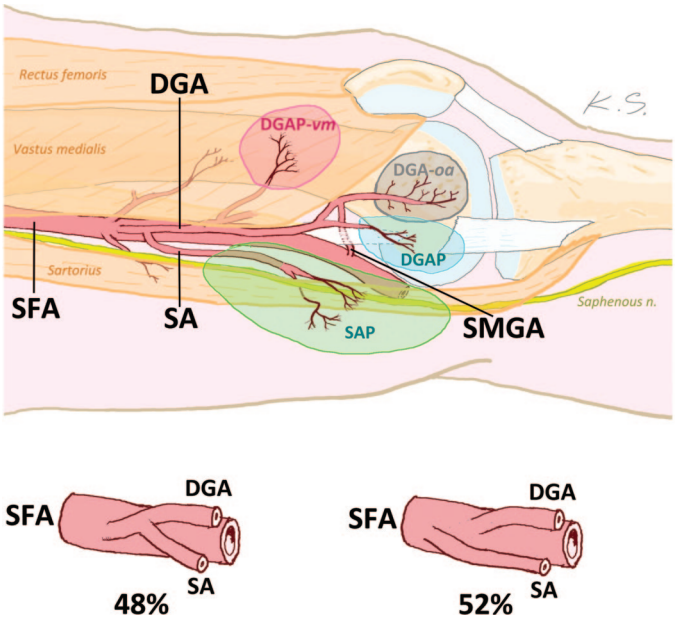

Fig. 1. Diagram of the main arteries supplying the skin of the medial knee and femoral condyle (*above*) and the variations on the origin of the saphenous artery (*below*): superficial femoral artery (*SFA*), descending genicular artery (*DGA*), superior medial genicular artery (*SMGA*), and saphenous artery (*SA*). The skin and bone perforators are shown with their presumed territories: the descending genicular artery perforator through the vastus medialis muscle (*DGAP*-vm), the distal-direct perforator of the descending genicular artery (*DGAP*), the combined perforator of the saphenous artery (*SAP*), and the osteoarticular branch of the descending genicular artery (*DGA*-oa).

pedicle has been advocated as the osteocutaneous descending genicular artery chimera flap.[5]

The universal acceptance of descending genicular artery free flaps has been somewhat limited by significant variations in vascular anatomy, which may impede the planning, preparation, and elevation of these flaps.[2–4] In addition, there is some confusion regarding the terminology of these flaps[13] because of inconsistent nomenclature of the perforator flap. We therefore considered it important to investigate the anatomical variations of the descending genicular artery and saphenous artery using a combination of vascular dissection and three-dimensional angiography in human cadavers.

MATERIALS AND METHODS

Thirty-one thighs from 16 fresh cadavers (six male and 10 female cadavers; average age, 70.8 years) were studied by injection of gelatin contrast medium into the femoral artery. The injection protocol was similar to that reported by Tang et al.,[14] but we used a green dye and contrast media instead of lead oxide because of the carcinogenic hazard of lead oxide after burning.

Anatomical dissection of the medial knee area, immediately above the joint line, was performed using surgical loupes with 3.3× magnification. The dissection area was approached through an anterior incision starting 1 cm medial to the patella and extending proximally to the mid thigh. The subcutaneous fat and fascia were dissected meticulously to expose the terminal branches, which had a distinctive color because of the green dye (Fig. 2). Every cutaneous perforator larger than 0.5 mm was preserved and dissected proximally to its source vessel. In case of musculocutaneous perforators, intramuscular dissection was carried out in a manner similar to perforator flap elevation. The plane of dissection progressed from the superficial to the deep structures between the vastus medialis and sartorius muscles until the superficial femoral artery was exposed. The saphenous artery was identified by its intimate contact with the saphenous nerve. After the vessels were skeletonized along their course to the super-

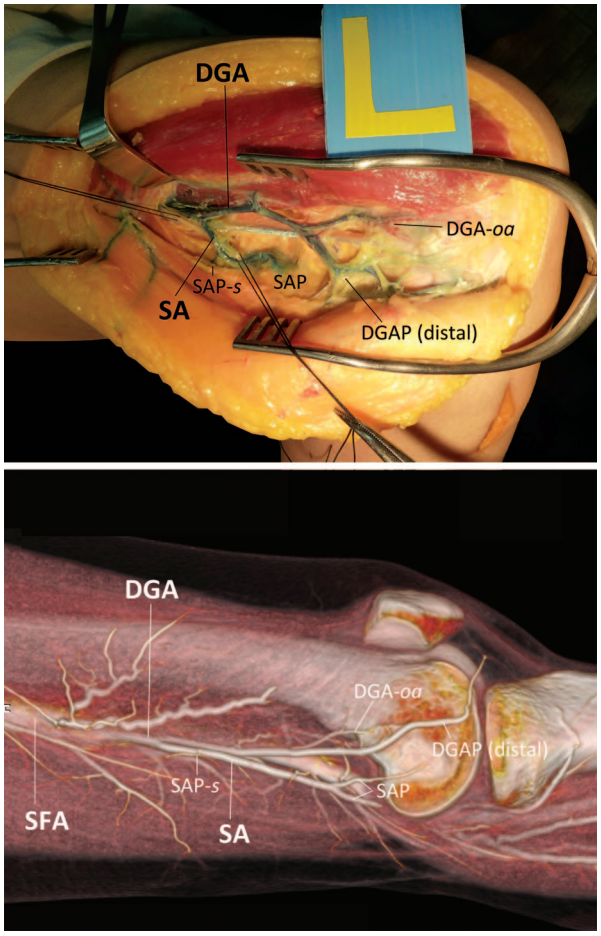

Fig. 2. (*Above*) Cadaveric dissection of the medial knee showing the main arteries; the saphenous nerve was tagged with black silk suture. In this specimen, the saphenous artery originates from the proximal part of the descending genicular artery and gives rise to two skin perforators. (*Below*) Three-dimensional angiographic image of the same specimen before dissection. *DGA*, descending genicular artery; *SFA*, superficial femoral artery; *SA*, saphenous artery; *SAP*, saphenous artery perforator; *DGAP*, descending genicular artery perforator; s, sartorius; vm, vastus medialis; oa, osteoarticular.

ficial femoral artery, their lengths and diameters were measured with a digital caliper. In each case, several photographs of the dissected vessels were obtained and a template diagram was drawn relating the vessels to the surrounding bony and muscular structures. Because surgical dissection may distort in situ vascular anatomy, in the initial dissections, we also performed three-dimensional angiography by means of 64-slice dual-source spiral computed tomography before anatomical dissection (Fig. 2). The angiographic findings served to verify the anatomical dissection findings.

The perforators' nomenclature and abbreviations in this study (Table 1) were modified from the Gent consensus on skin perforator flaps,[15] using the source vessel, end organ, and perforated structures. Perforators going directly to the skin or perforating a septum were considered direct, and those perforating a muscle were considered as musculocutaneous perforators (for the sartorius and for the vastus medialis). When a skin perforator had both direct and musculocutaneous divisions, it was considered as a combined skin perforator. The branches of the descending genicular artery and/or the superior medial genicular artery, which supply the medial femoral condyle, were considered as osteoarticular branches (Table 1). When a skin perforator had both direct and muscular divisions, it was named a combined skin perforator.

Because for vascular flaps the distance from the origin and diameter at the origin of the vascular branch are clinically important, we have summarized our findings for the saphenous artery, descending genicular artery, and superior medial genicular artery (Table 2). In addition, for chimeric osteocutaneous flaps, we defined the chimeric pedicle length as the distance between the origin of the descending genicular artery from the superficial femoral artery and the bifurcation of the skin and bone branches. The chimeric arm length was defined as the sum of the skin and bone branch lengths from the bifurcation to the end organ (Fig. 3). Although the former is relevant for the distance from the flap's recipient vessel, the latter is relevant for the distance between the bone and skin defects.

Lower limbs with signs of trauma, lacerations, surgical incisions, or punctures were excluded. The cadavers were derived from body donation with informed consent, written and signed (with signature authentication) by the donor. The protocol for the present research had been approved by the ethics committee of our institution. Statistical analysis was performed with the Kruskal-Wallis test using Stata Software version 8.2 (StataCorp, College Station, Texas).

RESULTS

The skin of the medial knee area and the medial femoral condyle received its blood supply from four distinctive arterial sources: the superficial femoral, saphenous, descending genicular, and superior medial genicular arteries (Fig. 1). Although the superficial femoral artery is the major source for the other three, it may also give skin perforators, which were noted in only 10 of the dissected thighs (32 percent). The saphenous artery, which can be recognized by its intimate course along the saphenous nerve, was noted in

Table 1. Perforator Nomenclature of the Medial Knee Region Modified after the Gent Consensus*

Source Vessel	Structure Perforated	End Organ	Name	Abbreviation
DGA	None or septum	Skin	DGA direct skin perforator	DGAP†
	Sartorius muscle	Skin	DGA sartorius skin perforator	DGAP-*s*†
	Vastus medialis muscle	Skin	DGA vastus medialis skin perforator	DGAP-*vm*†
	None	Osteoarticular	DGA osteoarticular branch	DGA-*oa*
SFA	None or septum	Skin	SFA direct skin perforator	SFAP†
	Sartorius muscle	Skin	SFA sartorius skin perforator	SFAP-*s*†
	Vastus medialis muscle	Skin	SFA vastus medialis skin perforator	SFAP-*vm*†
SA	None or septum	Skin	SA direct skin perforator	SAP
	Sartorius muscle	Skin	SA sartorius skin perforator	SAP-*s*
SMGA	None	Osteoarticular	SMGA osteoarticular branch	SMGA-*oa*

DGA, descending genicular artery; SFA, superficial femoral artery; SFAP, superficial femoral artery perforator; SA, saphenous artery; SAP, saphenous artery perforator; SMGA, superior medial genicular artery; DGAP, descending genicular artery perforator; *s*, sartorius; *vm*, vastus medialis; *oa*, osteoarticular.

*Blondeel PN, Van Landuyt KH, Monstrey SJ, et al. The "Gent" consensus on perforator flap terminology: Preliminary definitions. *Plast Reconstr Surg.* 2003;112:1378–1383; quiz 1383, 1516; discussion 1384–1377.

†Gent consensus abbreviation.

Table 2. Clinically Relevant Dimensions of the Descending Genicular, Saphenous, and Superior Medial Genicular Arteries

	DGA	SMGA	SA
No. of thighs	27	29	31
Length, mm			
Mean ± SD	81.6 ± 18.0	37.3 ± 8.4	51.9 ± 17.1
Range	52.5–126.0	18.3–54.9	26.2–77.2
Origin from joint line, mm			
Mean ± SD	128.3 ± 12.2	59.8 ± 9.1	—
Range	103.4–153.2	31.4–71.3	—
Diameter, mm			
Mean ± SD	2.7 ± 0.6	1.5 ± 0.7	2.1 ± 0.8
Range	1.8–3.8	0.5–3.0	1.3–3.8

DGA, descending genicular artery; SMGA, superior medial genicular artery; SA, saphenous artery.

our study to be present in all 31 thighs; in 16 (52 percent), it originated from the superficial femoral artery, whereas in the remainder it originated from the descending genicular artery (Fig. 1). The descending genicular artery, which typically arises from the superficial femoral artery, has both skin perforators and osteoarticular branches supplying the medial femoral condyle. In our study, it was noted in 27 thighs (87 percent), and in the four thighs in which it was absent, the superior medial genicular artery was the dominant artery of the medial femoral condyle and the skin perforators in this area originated from the saphenous and superficial femoral arteries (Fig. 4). The superior medial genicular artery, which typically arises from the popliteal artery, was present in 29 thighs (94 percent), giving rise to osteoarticular branches to the medial femoral condyle, and in only one thigh, it also had a skin perforator. In Table 2, we show the clinically relevant dimensions of the saphenous, descending genicular, and superior medial genicular arteries.

Skin Perforators of the Superficial Femoral, Descending Genicular, and Saphenous Arteries

Superficial femoral artery skin perforators were noted in 10 thighs (32 percent), half of which were direct skin perforators, and the remaining were musculocutaneous going through the sartorius and vastus medialis muscles (Table 3). The saphenous artery skin perforators were direct in 14 thighs, musculocutaneous through the sartorius muscle in 11, or combined with both direct and sartorius branches in six of the 31 thighs. However, we could not find any saphenous artery musculocutaneous perforator that went through the vastus medialis muscle. The descending genicular artery gave rise to more than one skin perforator in 19 thighs (70 percent) of the 27 thighs in which it was present (Table 3), most commonly two perforators (in 44 percent). The most common (54 percent) were direct skin perforators, arising from the distal third of the descending genicular artery. Less commonly (46 percent), the skin perforators arose from the proximal or middle third of the descending genicular artery, half of which were musculocutaneous through the vastus medialis muscle (Fig. 5) and the remaining were direct skin perforators. We could not find any musculocutaneous perforator of the descending genicular artery going through the sartorius muscle, except for one thigh with a combined sartorius muscle skin perforator (Table 4).

Osteoarticular Branches of the Descending Genicular Artery and Superior Medial Genicular Artery

The medial femoral condyle was noted to receive its blood supply by osteoarticular branches from both the descending genicular and superior

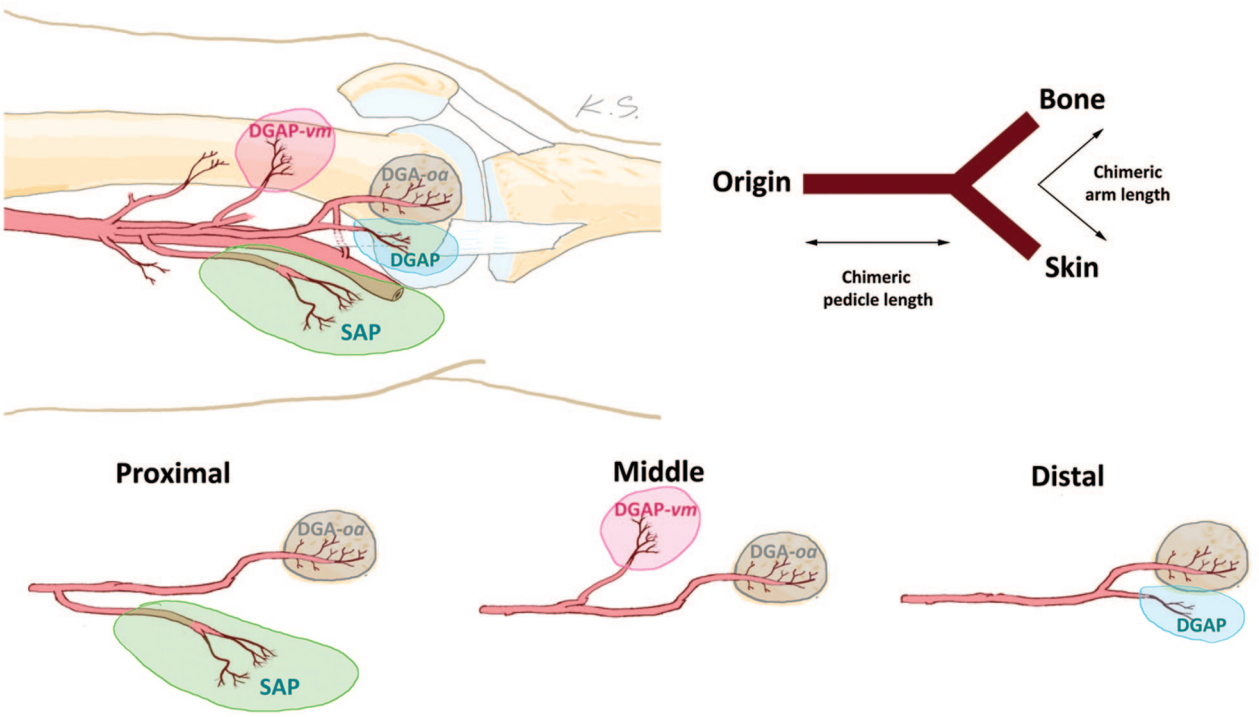

Fig. 3. Diagram of the skin and bone perforators of the descending genicular artery and saphenous artery, which are used in chimeric osteocutaneous flaps (*above*, *left*); the definitions of the chimeric pedicle and arm lengths (*above*, *right*); and the use of various combinations of skin perforators arising from the proximal, middle, and distal thirds of the descending genicular artery (*below*). *DGA*, descending genicular artery; *SAP*, saphenous artery perforator; *DGAP*, descending genicular artery perforator; vm, vastus medialis; oa, osteoarticular.

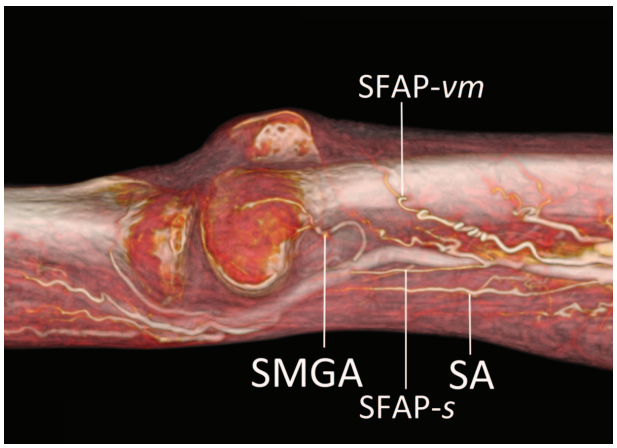

Fig. 4. A three-dimensional angiogram showing absence of the descending genicular artery. In this specimen, the superior medial genicular artery was the dominant artery of the medial femoral condyle, and the main skin perforators in this area originated from the saphenous artery and superficial femoral artery. *SFAP*, superficial femoral artery perforator; *SA*, saphenous artery; *SMGA*, superior medial genicular artery; s, sartorius; vm, vastus medialis.

Table 3. Number and Type of Skin Perforators Originating from Superficial Femoral, Saphenous, and Descending Genicular Arteries

Source Vessel	No. of Thighs	Total No. of Perforators	Type of Perforator			
			Direct	*s*	*d/s*	*vm*
SFA	10	14	7	2	—	5
SA*	31	31	14	11	6	—
DGA	27	39†	29	—	1	9

s, sartorius; *d/s*, combined direct and sartorius; *vm*, vastus medialis; SFA, superficial femoral artery; SA, saphenous artery; DGA, descending genicular artery.
*Including perforators of the SA when it originates from the DGA.
†Two perforators in 12 thighs, three perforators in six thighs, and four perforators in one thigh.

medial genicular arteries in 25 thighs (81 percent), with the descending genicular artery as the major contributor, in four (13 percent) only from the superior medial genicular artery and in two (6 percent) only by the descending genicular artery.

Skin and Bone Combinations of the Descending Genicular/Saphenous Artery Branches (Osteocutaneous Chimera)

Osteocutaneous chimera can be used for deficits in both bone and skin using the descending

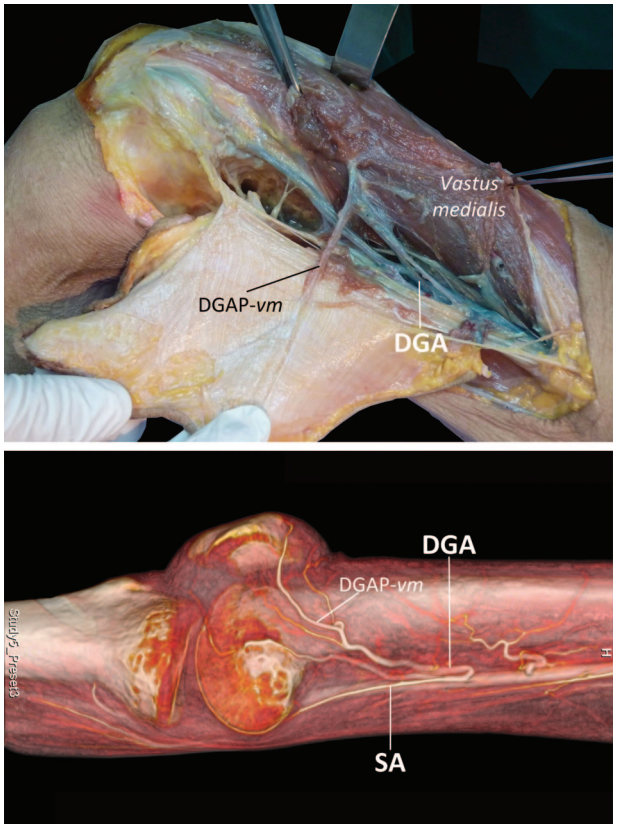

Fig. 5. The descending genicular artery perforator going through the vastus medialis (*DGAP*-vm) from the proximal part of the descending genicular artery (*DGA*) is demonstrated after intramuscular dissection (*above*) and in a three-dimensional angiographic study (*below*). In this specimen, the saphenous artery (*SA*) arises from the proximal part of the descending genicular artery.

genicular artery (Fig. 3). In Table 5, we show the calculated lengths of the chimeric pedicle and arm in each specimen, using the descending genicular artery osteoarticular branches and the descending genicular artery skin perforators or the saphenous artery skin perforators, when the saphenous artery originates from the descending genicular artery ($n = 15$ thighs). Obviously, the chimeric pedicle length increases and the chimeric arm length decreases, as the descending genicular artery skin perforators are more distally located. However, we could not find a significant difference in these lengths between the saphenous artery skin perforators and the proximal descending genicular artery skin perforators (Kruskal-Wallis test, $p = 0.1$ and $p = 0.3$ for the arm and pedicle lengths, respectively).

CASE REPORTS

Case 1

A 49-year-old man presented with a whole-skin loss of 12 × 15 cm on the dorsal aspect of the right hand following snakebite. The medial aspect of the knee was selected as the donor site because of its thin and minimally hirsute appearance. A descending genicular artery perforator with the vastus medialis pedicle was isolated, requiring intramuscular dissection during flap elevation. The flap survived totally, resulting in good appearance after 4 months (Fig. 6).

Table 4. Number and Origin of the Descending Genicular Artery Skin Perforators*

	DGA Third		
	Proximal	Middle	Distal
DGAP	5	3	21
DGAP-*s*	0	0	0
DGAP-*d/s*	1	0	0
DGAP-*vm*	5	4	0
Total no.	11	7	21

DGA, descending genicular artery; DGAP, descending genicular artery perforator; *s*, sartorius; *d/s*, direct and sartorius; *vm*, vastus medialis.
*Excluding the perforators of the SA when it arises from the DGA.

Case 2

A 39-year-old-man presented after a motorcycle accident that resulted in a 6 × 10-cm skin and 4-cm carpal/metacarpal bone loss. A chimeric osteocutaneous free flap was harvested using the osteoarticular branch of the descending genicular artery with a cortical-periosteal part of the medial femoral condyle and the middle-third descending genicular artery perforator with its accompanying skin and medial femoral cutaneous nerve. A radiograph 4 months after the operation shows complete bony union of the involved metacarpal bones, and examination of the flap showed S3 sensate skin (Fig. 7).

DISCUSSION

This fresh cadaveric study is one of the largest series detailing the arterial variations in the skin and bone blood supply of the medial knee, which are relevant for the formation of free vascular flaps. Previous reports included anatomical findings from both cadavers and clinical cases of free flaps,[1,3,5,16–18] one of which was from several "widely separated centers."[1] In addition, four series on pedicle flaps included cadaveric thighs and clinical cases.[19–22] Because of the limited information on anatomical variations in clinical cases, we chose not to report data obtained from vascular flap dissections in this report. Also, small skin perforators may escape detection after cadaveric preservation, and fresh cadavers more closely reflect the in vivo findings. In our study, we also combined three-dimensional angiography before anatomical dissection to verify our findings. Recently, Tang et al.[14] showed that three-dimensional angiography in cadavers could capture the intricate vascular details of the skin, bone, and soft tissue in a layer-by-layer transparent process. Although our study evaluated the arterial variations of the saphenous, descending genicular, superfi-

Table 5. Chimeric Pedicle and Arm Lengths of Flaps Using the Descending Genicular Artery Osteoarticular Branches Combined with Skin Perforators from the Saphenous and Descending Genicular Arteries

	Skin Perforators			
	SA	DGA Proximal	DGA Middle	DGA Distal
No. of thighs	15	11	7	21
Chimeric pedicle length				
Mean ± SD	11.6 ± 11.7†	10.2 ± 7.5†	43.2 ± 4.3	68.0 ± 21.0
Range	0–45.6	0–26.4	37.2–50.0	37.2–126.0
Chimeric arm length				
Mean ± SD	117.2 ± 15.7*	149.8 ± 37.0*	96.7 ± 23.9	47.0 ± 15.7
Range	94.8–145.7	98.5–206.0	64.1–128.9	9.0–64.8

SA, saphenous artery; DGA, descending genicular artery.
No statistically significant difference between means (Kruskal-Wallis test, *$p = 0.1$ and †$p = 0.3$).

cial femoral, and superior medial genicular arteries that are relevant for skin and/or bone free vascular flaps, other reports focused on the saphenous artery free skin flaps,[1,17,18] saphenous artery pedicle flaps,[19–22] descending genicular artery and superior medial genicular artery bone flaps,[23,24] descending genicular artery adductor magnus and saphenous artery skin flaps,[16] and descending genicular artery and saphenous artery skin/bone flaps.[5] Some of these series[1,16,18] also used the skin below the knee joint (distal saphenous artery territory), whereas in our study we focused only on the medial aspect of the skin above the knee joint. The nomenclature of the vascular branches of the main arteries in this area is still not uniformly accepted, resulting in confusion in the terminology of perforator flaps.[15,25–27] Although the Gent consensus is the officially accepted nomenclature for this area, it has been criticized by some authors.[25,27] In the current study, we have slightly modified the Gent consensus to describe our findings, by including also the saphenous artery skin perforators and the osteoarticular branches of the descending genicular artery. Because the Gent consensus terminology depends on the source vessel and the saphenous artery is not recognized as a separate source, the saphenous artery perforators receive their names depending on their origin (from the descending genicular artery or superficial femoral artery). However, the saphenous artery can be easily identified by its intimate anatomical relation to the saphenous nerve, and in half the thighs, it originates from the superficial femoral artery; in the other half, it originates from the descending genicular artery. We suggest, therefore, that recognizing the saphenous artery as another "source vessel" in the Gent consensus will enhance its consistency and universality.

Our findings show that there are several sources of skin perforators in the medial knee that can be used for vascular flaps. Although the saphenous artery was present in all thighs, the descending genicular artery was noted in the majority (87 percent), and when it was absent, the saphenous artery could be used instead. In addition, the superficial femoral artery offers skin perforators in 32 percent of the thighs, which can be used for this purpose clinically.[18] The descending genicular artery, which usually has more than one skin perforator, offers greater arterial diameter and length than the saphenous artery. However, the saphenous artery has been reported to perfuse a wider skin area[5] and may be used for larger skin defects. An important finding in our study is that the saphenous artery originates from the descending genicular artery in only half of the specimens, whereas in the remaining specimens, it originates from the superficial femoral artery. This has not been universally appreciated in other studies, which suggested that the saphenous artery originates in all or in the majority of cases from the descending genicular artery.[1,16,17] Another large series (37 thighs) also noted that the saphenous artery originates from the descending genicular artery in 67 percent.[20] This discrepancy may be explained by proximity of the origins of the descending genicular artery and saphenous artery from the superficial femoral artery or by isolating a descending genicular artery perforator, which also runs close to the saphenous nerve. Although this finding may seem to bear little significance for skin flaps, it plays an important role in chimeric flaps.

Another important finding in our study is that approximately half of the saphenous artery skin perforators are direct and the remaining are musculocutaneous or combined perforators. Of the descending genicular artery skin perforators, direct perforators accounted for all those arising from the distal third but only approximately half of those arising from the proximal and middle thirds of the descending genicular artery. Interestingly, we found that most of the musculocuta-

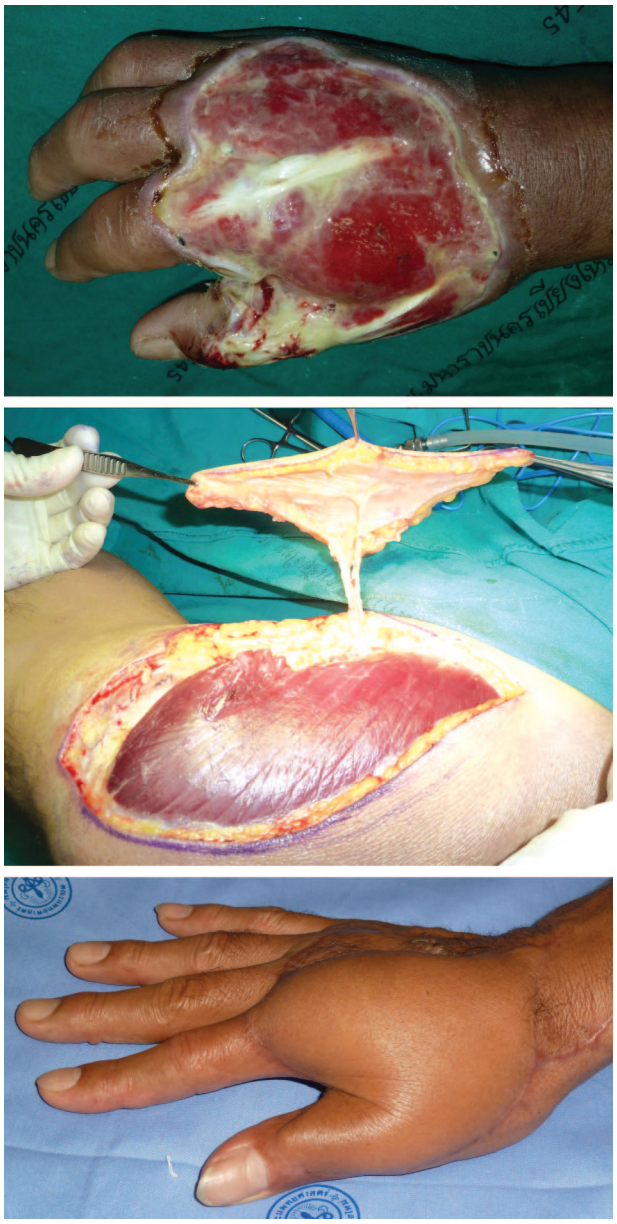

Fig. 6. Case 1. The right hand with a 12 × 15-cm skin defect before reconstruction (*above*). Intramuscular dissection of the descending genicular artery perforator with the vastus medialis during flap elevation (*center*). The same hand after successful medial knee skin flap surgery, 4 months after reconstruction (*below*).

neous perforators of the saphenous artery were associated with the sartorius muscle, whereas those of the descending genicular artery were associated with the vastus medialis muscle; this finding has not been reported previously. During the isolation and preparation of skin flaps, this may serve as an important anatomical landmark. Although the use of the distal descending genicular artery direct skin perforators has been reported by others,[3–5] the use of these perforators with the vastus medialis has not been reported previously. We suggest that the distal descending genicular artery direct skin perforators with the vastus medialis can also be used for free vascular flaps, although it is present in less than one-third of the thighs and requires intramuscular dissection. Its presence should be recognized, however, because if it is accidentally ligated during flap elevation, another perforator flap should be attempted.

The osteoarticular branches of the descending genicular artery have been used increasingly over the past two decades for vascular bone grafts in various clinical situations.[6–12] However, only a few studies have examined the anatomical variations of these vessels in cadavers. Our findings suggest that both the descending genicular and superior medial genicular arteries supply the medial femoral condyle, but the former has greater length and diameter than the latter and in 87 percent is the dominant artery (including 6 percent where the superior medial genicular artery was absent). In the remaining 13 percent, the descending genicular artery was absent and the superior medial genicular artery was the only vessel supplying the medial femoral condyle. Clinical series of vascular bone flaps often mention this occurrence and suggest using the superior medial genicular artery instead.[6,9] Reviewing the literature, which studied the arterial blood supply of the medial femoral condyle in fresh cadavers, the authors also report that the descending genicular artery was present in 85 percent[24] and 89 percent,[23] but the superior medial genicular artery was present in all of their specimens.

Chimeric flaps, combining both osteoarticular and skin perforators, have been used in a wide range of complex skin and bone injuries.[3–5,9,16] Compared with other chimeric flaps, the medial femoral condyle chimeric flap seems relatively easy to harvest, reshape, and inset into the recipient site. Some concern has been raised regarding the feasibility of the descending genicular artery chimeric flap because of the anatomical variations of its skin perforators.[2–4] Our study suggests, however, that in each specimen a skin perforator originating from the descending genicular artery can be allocated; namely, the saphenous artery or the other descending genicular artery skin perforators (descending genicular artery perforators or descending genicular artery perforators with vastus medialis). When the descending genicular artery is absent (13 percent of the thighs in this series), more sophisticated approaches should be used,[28,29] and only preoperative computed tomographic angiography will

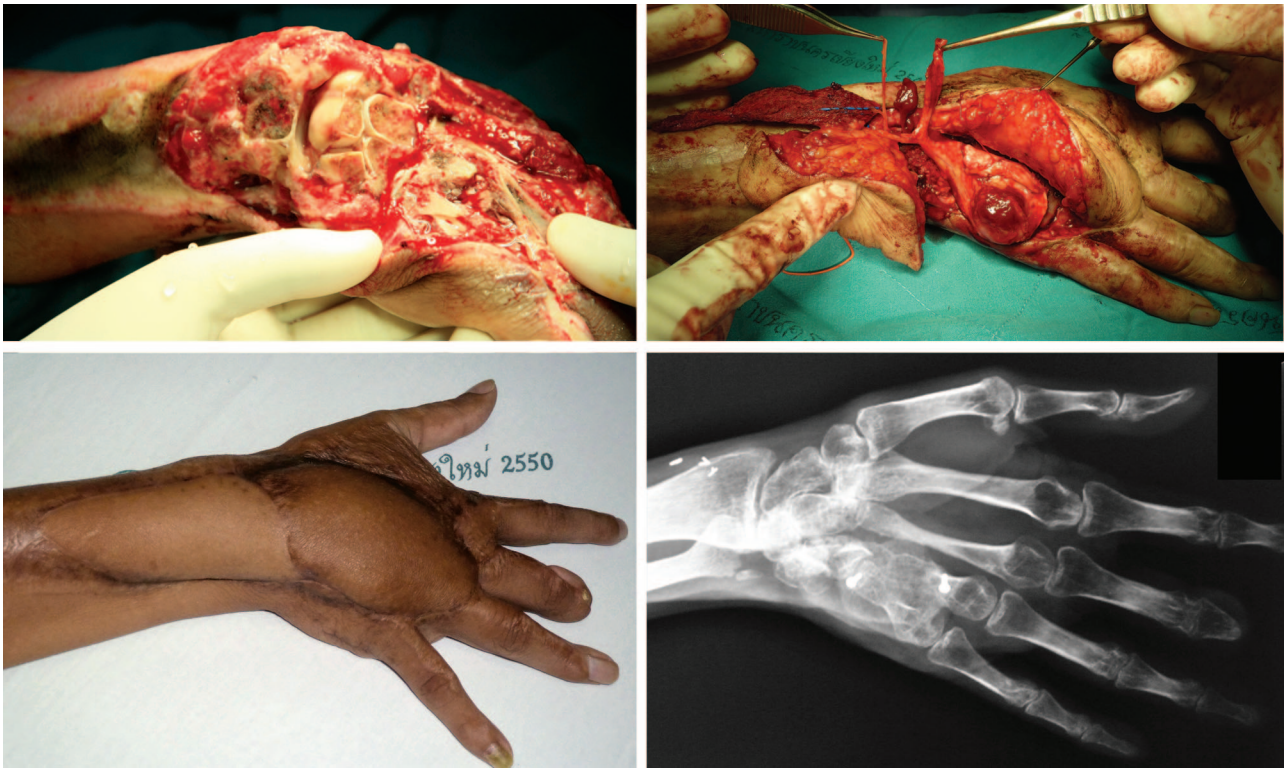

Fig. 7. Case 2. Bone and skin injury of the right hand before reconstruction (*above*, *right*). The insetting of the chimeric osteocutaneous flap, using the descending genicular artery osteoarticular and descending genicular artery perforator with the vastus medialis from the middle third of the descending genicular artery (*above*, *left*). The same hand after successful osteocutaneous descending genicular artery flap surgery, 4 months after reconstruction (*below*, *left*). Radiograph of the same hand showing bony union 4 months after reconstruction (*below*, *right*).

identify this condition. In our study, we propose the chimeric pedicle and arm lengths as important parameters in the decision regarding which skin perforator to choose for a chimeric flap. Using the distal descending genicular artery skin perforators with the osteoarticular branch of the descending genicular artery offers a long vascular pedicle but a short chimeric arm, which is most suitable for "buoy" flaps. This has also been suggested in clinical series.[5] In contrast, the saphenous and proximal descending genicular artery skin perforators offer a short pedicle length and wide chimeric arm, which is most appropriate in cases where there is a wide gap between the skin and bone defects. Our findings suggest that in general there is no significant advantage to choosing the saphenous artery over the other proximal perforators, as far as the chimeric dimensions are concerned. However, it appears that the saphenous artery offers a wider skin territory than the other descending genicular artery perforators.[5]

CONCLUSIONS

This study investigated the anatomical variations in the skin and bone perforators of the medial knee. A free skin flap may be achieved in all of the specimens with skin perforators from the saphenous, descending genicular, or superficial femoral artery. For free vascular bone grafts, the descending genicular artery offers greater length and diameter than the superior medial genicular artery but was absent in 13 percent of the thighs; in these cases, the superior medial genicular artery may be used. The skin perforators of the descending genicular artery could be combined with osteoarticular branches of the descending genicular artery to form chimeric flaps in 87 percent of the thighs. These flaps offer a range of chimeric arm and pedicle lengths, which can meet varying distances of skin and bone defects.

Kanit Sananpanich, M.D.
Department of Orthopedics
Faculty of Medicine
Chiang Mai University
Chiang Mai 50200, Thailand
ksananpa@gmail.com

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Professor Dan J. Sherman, their research consultant, who improved the

article, and Sumran Dansirikul, who obtained the computed tomographic scans and performed the three-dimensional reconstruction.

REFERENCES

1. Acland RD, Schusterman M, Godina M, Eder E, Taylor GI, Carlisle I. The saphenous neurovascular free flap. *Plast Reconstr Surg.* 1981;67:763–774.
2. Blondeel PN, Morris AM, Hallock G, Neligan PC, eds. *Perforator Flaps: Anatomy, Technique and Clinical Applications.* Vol. 2, 1st ed. St. Louis: Quality Medical; 2006.
3. Martin D, Bitonti-Grillo C, De Biscop J, et al. Mandibular reconstruction using a free vascularised osteocutaneous flap from the internal condyle of the femur. *Br J Plast Surg.* 1991; 44:397–402.
4. Pelzer M, Reichenberger M, Germann G. Osteo-periosteal-cutaneous flaps of the medial femoral condyle: A valuable modification for selected clinical situations. *J Reconstr Microsurg.* 2010;26:291–294.
5. Iorio ML, Masden DL, Higgins JP. Cutaneous angiosome territory of the medial femoral condyle osteocutaneous flap. *J Hand Surg Am.* 2012;37:1033–1041.
6. Bakri K, Shin AY, Moran SL. The vascularized medial femoral corticoperiosteal flap for reconstruction of bony defects within the upper and lower extremities. *Semin Plast Surg.* 2008;22:228–233.
7. Cavadas PC, Landin L. Treatment of recalcitrant distal tibial nonunion using the descending genicular corticoperiosteal free flap. *J Trauma* 2008;64:144–150.
8. Sakai K, Doi K, Kawai S. Free vascularized thin corticoperiosteal graft. *Plast Reconstr Surg.* 1991;87:290–298.
9. Doi K, Hattori Y. Vascularized bone graft from the supracondylar region of the femur. *Microsurgery* 2009;29:379–384.
10. Jones DB Jr, Burger H, Bishop AT, Shin AY. Treatment of scaphoid waist nonunions with an avascular proximal pole and carpal collapse: A comparison of two vascularized bone grafts. *J Bone Joint Surg Am.* 2008;90:2616–2625.
11. Doi K, Oda T, Soo-Heong T, Nanda V. Free vascularized bone graft for nonunion of the scaphoid. *J Hand Surg Am.* 2000; 25:507–519.
12. Doi K, Sakai K. Vascularized periosteal bone graft from the supracondylar region of the femur. *Microsurgery* 1994;15: 305–315.
13. Geddes CR, Morris SF, Neligan PC. Perforator flaps: Evolution, classification, and applications. *Ann Plast Surg.* 2003; 50:90–99.
14. Tang M, Yin Z, Morris SF. A pilot study on three-dimensional visualization of perforator flaps by using angiography in cadavers. *Plast Reconstr Surg.* 2008;122:429–437.
15. Blondeel PN, Van Landuyt KH, Monstrey SJ, et al. The "Gent" consensus on perforator flap terminology: Preliminary definitions. *Plast Reconstr Surg.* 2003;112:1378–1383; quiz 1383, 1516; discussion 1384–1377.
16. Huang D, Wang HW, Xu DC, Wang HG, Wu WZ, Zhang HR. An anatomic and clinical study of the adductor magnus tendon-descending genicular artery bone flap. *Clin Anat.* 2011;24:77–83.
17. Lee SH, Choi TH, Kim SW, et al. An anatomical study of the saphenous nerve, artery, and its perforators within the thigh using cadaveric dissection. *Ann Plast Surg.* 2011;67:413–415.
18. Karamürsel S, Celebioğlu S. Use of the medial side of the knee skin as a free flap: Saphenous flap. *Plast Reconstr Surg.* 2006;117:1308–1314.
19. Bertelli JA. The saphenous postero-medial cutaneous island thigh flap and the saphenous supero-medial cutaneous island leg flap (25.10.91). *Surg Radiol Anat.* 1992;14:187–189.
20. Tang ML, Liu XY, Ren JW, et al. The sartorius myocutaneous island flap. *Surg Radiol Anat.* 1993;15:259–263.
21. Lu LJ, Gong X, Cui JL, Liu B. The anteromedial thigh fasciocutaneous flap pedicled on the supragenicular septocutaneous perforator: Application in 11 patients. *Ann Plast Surg.* 2011;67:275–278.
22. Hertel R, Masquelet AC. The reverse flow medial knee osteoperiosteal flap for skeletal reconstruction of the leg: Description and anatomical basis. *Surg Radiol Anat.* 1989;11: 257–262.
23. Yamamoto H, Jones DB Jr, Moran SL, Bishop AT, Shin AY. The arterial anatomy of the medial femoral condyle and its clinical implications. *J Hand Surg Eur Vol.* 2010;35:569–574.
24. Hugon S, Koninckx A, Barbier O. Vascularized osteochondral graft from the medial femoral trochlea: Anatomical study and clinical perspectives. *Surg Radiol Anat.* 2010;32: 817–825.
25. Kim JT. New nomenclature concept of perforator flap. *Br J Plast Surg.* 2005;58:431–440.
26. Hallock GG. Direct and indirect perforator flaps: The history and the controversy. *Plast Reconstr Surg.* 2003;111:855–865; quiz 866.
27. Sinna R, Boloorchi A, Mahajan AL, Qassemyar Q, Robbe M. What should define a "perforator flap"? *Plast Reconstr Surg.* 2010;126:2258–2263.
28. Hallock GG. Further clarification of the nomenclature for compound flaps. *Plast Reconstr Surg.* 2006;117:151e–160e.
29. Koshima I. A new classification of free combined or connected tissue transfers: Introduction to the concept of bridge, siamese, chimeric, mosaic, and chain-circle flaps. *Acta Med Okayama* 2001;55:329–332.