The Effect of Graft Harvest and Skin Incision Angle on Sensory Disturbance in ACL Reconstruction With Semitendinosus-Gracilis Tendon Graft

A Randomized Controlled Trial and Cadaveric Study

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Background: Injury to the inferior branch of the saphenous nerve (IBSN) and the subsequent loss of skin sensation after anterior cruciate ligament (ACL) reconstruction are common. The literature suggests that the incision angle may affect the incidence and area of loss of skin sensation.

Purpose: To determine whether there is a difference in the incidence and area of altered sensory loss on the tibia between vertical (VI) and oblique (OI) incisions for semitendinosus-gracilis tendon graft harvest during ACL reconstruction. The cadaveric component was designed to determine whether there is a "safe zone" for incision by identifying the location and number of branches of the IBSN.

Study Design: Randomized controlled trial; Level of evidence, 2.

Methods: Patients (n = 37) were randomized to receive either VI or OI. Incidence and area of altered skin sensation were documented during at least 1 postoperative visit. In addition, 18 cadaveric knees were dissected.

Results: The presence or absence of hypoesthesia did not differ between groups postoperatively. Although no statistical differences between groups were seen in the total area of perceived altered skin sensation at 3 ($P = .57$), 6 ($P = .08$), 12 ($P = .65$), and 24 months ($P = .27$), data demonstrated a trend toward VI participants having a larger area of hypoesthesia at every time point. Among the 18 cadaveric specimens, 4 variations in the distribution of IBSN were noted: 18 (100%) had 1 branch, 14 (78%) had 2 branches, 6 (33%) had 3 branches, and 1 (6%) had 4 branches. No safe zone for incision could be identified.

Conclusion: No difference was found between a vertical and an oblique incision with respect to incidence or area of sensory loss. Furthermore, it was not possible to identify a safe zone that would prevent transection of all nerves branches of the IBSN based on the cadaveric component of this study.

Keywords: anterior cruciate ligament; inferior branch of saphenous nerve; hypoesthesia; vertical incision; oblique incision

A common complication associated with anterior cruciate ligament (ACL) reconstructive surgery using semitendinosus and gracilis autograft (STG) is injury to the inferior branch of the saphenous nerve (IBSN) caused when the incision is made during graft harvest.[3,6-8,10,11,14,16,18] The incidence of this complication has been reported to be as high as 84%.[6] Some authors have proposed changing the incision angle from vertical to oblique in an effort to decrease the incidence of injury to the IBSN.[7] Other authors have reported no difference in injury to the IBSN with an oblique incision angle.[6,18] In a 2017 review, Ruffilli et al[15] reported that definitive conclusions could not be made with respect to incision angle because, at that time, no well-designed randomized controlled trials (RCTs) had been performed. The authors did indicate that evidence from clinical and anatomic studies suggested that an oblique incision may be preferred. More recently, a meta-analysis reported that a vertical incision had almost twice the risk of nerve injury as a horizontal or an oblique incision, with the oblique incision having the lowest risk of

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injury.[13] A cadaveric study to determine whether there is an IBSN "safe zone" in which the risk of cutting branches of the nerve is reduced is also warranted.

At the time of the current study's initiation, well-designed prospective RCTs to address this controversy were warranted to provide insight into possibly decreasing the incidence of IBSN injury. The purpose of the clinical aspect of this study was to compare the vertical and oblique incision approaches to determine whether there was a difference in the presence or absence of sensory loss as well as the size of the affected area of sensory loss on the tibia. The purpose of the cadaveric component of this study was to determine whether there is a safe zone for incision by identifying the number and pathways of branches of the IBSN. Identification of a safe zone might indicate a location and length of incision that would minimize the risk of cutting a nerve and leading to sensory loss.

Our hypothesis was that there would be a difference in the presence or absence of hypoesthesia or in the affected surface area (cm^2) of sensory loss between the vertical and oblique incision groups. Furthermore, there would be no universal safe zone for incision due to variability in the number and location of branches of the saphenous nerve identified on cadaveric specimens.

METHODS

Clinical Study

This was a single-center, prospective, parallel, balanced RCT with 2 groups: ACL reconstruction using a vertical incision (VI) for STG graft harvest or using an oblique incision (OI) for STG graft harvest. All study activities were approved by the local research ethics board. All patients between 2005 and 2008 who were identified by the contributing surgeon as having a complete ACL rupture during orthopaedic consultation were screened for eligibility. Inclusion criteria included patients 18 years of age or older, clinical and magnetic resonance imaging (MRI) evidence of a complete ACL tear, and willingness to participate in the trial. Participants were excluded if 1 or more of the following criteria were identified: previous knee surgery (including arthroscopy), prior major trauma to skin or soft tissues in the infrapatellar region (old scarring), gross obesity (body mass index >30 kg/m^2 as determined by the surgeon), visibly altered knee anatomic features, diabetes, documented neurological condition, postoperative saphenous hypoesthesia or neuralgia along the distribution of the main saphenous nerve (medial calf and medial ankle area), pregnancy, collagen disease, ongoing workers' compensation claim, and other medical conditions that precluded participation.

Patients consented and were enrolled by an independent research assistant, and all participants gave informed consent before any study activities took place. Patients were assessed before surgery and at 3, 6, 12, and 24 months after surgery (Figure 1). Randomization occurred intraoperatively once eligibility was confirmed. A series of opaque and sealed envelopes were created before the start of the study, each containing study group allocation generated through randomization software. Our primary outcome measure was the presence or absence of altered sensation defined as <5 cm^2 of surface area affected on the tibia surrounding or below the incision site. Secondary outcome measures were the cross-sectional area (CSA) of loss of skin sensation and the ACL quality of life (QoL) score.[9]

Based on the presence or absence of altered sensation, sample size was estimated to be 22 patients per group, assuming a clinically meaningful reduction in the presence of altered skin sensation to be 40%, with alpha at .05 and power at 0.80. An additional sample size estimate was derived based on CSA. Ejerhed et al[2] documented the median surface area involved in infrapatellar neuralgia to be 78 cm^2, with a range of 0 to 342 cm^2. These values were not normally distributed, and there was no reported standard deviation. We assumed that a 50% difference in the affected surface area would be deemed clinically significant; thus, we estimated that the reduction in affected area would result in a mean affected surface area of 39 cm^2. Using previous reports within the literature,[13,15] we projected an SD of 55 cm^2. Using an unpaired 2-sample Student *t* test to detect a statistical difference at 0.05% between primary outcome measures at a power of 0.8, we estimated that this study required 33 patients in each group. Recruitment to this study was terminated early, because we believed there was mounting evidence that either supported the use of the OI or found no difference, and the benefit to the surgeon intraoperatively outweighed any further benefit to recruiting to the study.

Patients were randomized intraoperatively to 1 of the 2 study groups: VI or OI. All surgeries were performed by the senior author (P.M.). Patients were placed supine with a free limb draping of the leg, and general or epidural anesthetic was administered. For the OI group, a 4-cm incision was made in oblique fashion 50° from horizontal, starting 5 cm medial from middle of tibial tubercle, measured in flexed position. The incision proceeded superior and medial from that point along a 50° angle from horizontal (Figure 2).

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Ethical approval for this study was obtained from the Biomedical Research Ethics Board and the University of Manitoba (protocol No. B2004:222).

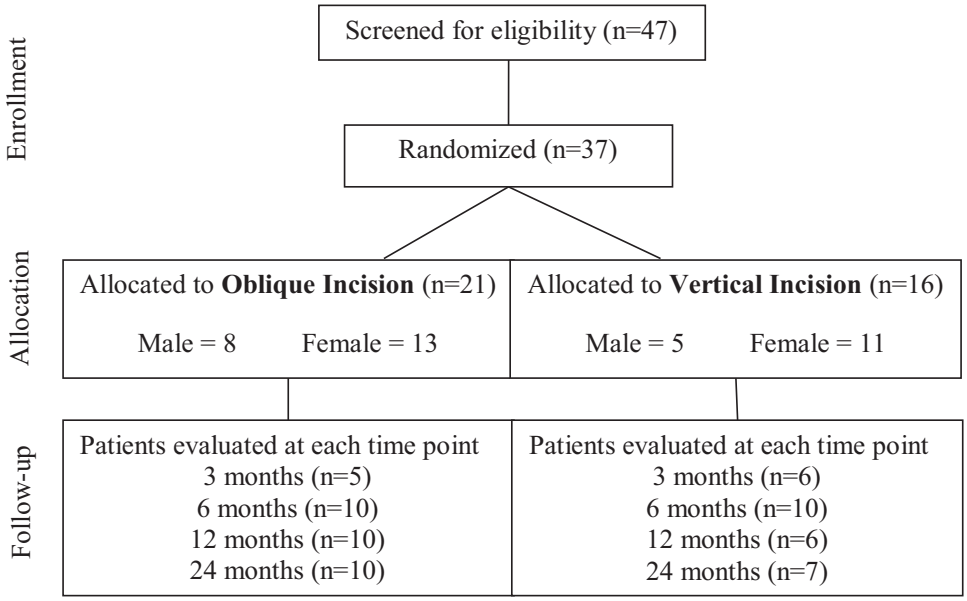

Figure 1. Patient flowchart.

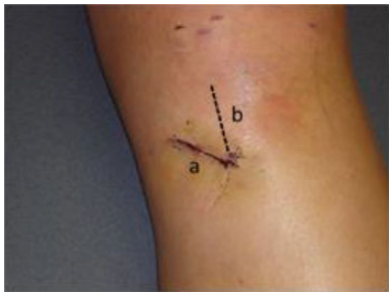

Figure 2. Orientation and length of oblique (*a*) and vertical (*b*) incisions at the 2-week postoperative follow-up visit.

For the VI group, a 4-cm incision was made in a vertical fashion, 3 cm medial to the tibial tuberosity, and proceeded inferior from that point.

Once the respective incision was made, dissection was carried down to the pes anserine bursa and the skin was undermined to assist in exposure. The insertion of the sartorius muscle was identified, and the tendons of the STG muscles were palpated under the fascia. After the superficial fascia was divided, the surgeon harvested the tendons using a tendon stripper after carefully freeing fascia around the tendons. The tendons were removed and taken to a separate table for preparation. The remainder of the procedure was carried out according to the standard procedure of the senior author.

During at least 1 follow-up appointment, a piece of tracing paper was placed over the surgical knee of the participants. The investigator marked the tibial tubercle, the medial and lateral joint lines, and the inferior surface of the patella. Patients were then asked to trace the area of sensory loss on the paper. The tracing paper was scanned using a goniometer for a scaling factor, and images were uploaded into National Institutes of Health (NIH) ImageJ software. Once images were uploaded, the CSA of sensory loss was determined by using the tracing tool in NIH ImageJ software. Participants were also required to complete the ACL QoL score at each follow-up visit. Because this was a surgical trial where the skin incision is an obvious indicator of which group the participant belongs to, neither the surgeon nor the participant could be blinded. However, the independent evaluator who computed the affected surface area was blinded to the type of treatment each participant received.

Descriptive statistics were generated for patient demographic data. A chi-square test was performed to evaluate the presence or absence of altered sensation between groups postoperatively. Paired t tests were performed to determine within-group changes in time for CSA of sensory loss and ACL QoL score. A priori, a series of 2 independent group t tests were to be performed to compare ACL QoL and CSA between groups at each time point. However, ACL QoL and CSA were evaluated at each time point for normality by use of the Shapiro-Wilk test, and CSA did not follow a normal distribution. Therefore, post hoc Mann-Whitney U tests were conducted to compare CSA between groups. All statistical tests were performed using SPSS 22.0 (IBM Corp). Statistical tests were considered significant at alpha equal to .05.

Cadaveric Study

Before this portion of the investigation began, ethics approval of methods that were incompliance with the Human Tissue Act of the province of Manitoba was ethics approval was obtained from the local institutional research ethics board, and all methods complied fully with the

Human Tissue Act of the province of Manitoba. After pilot testing of a dissection protocol modified from a format described by other investigators,[1,4,11] the right lower extremities of 18 embalmed cadavers were dissected to expose the course and distribution of the saphenous nerve from the level of the femoral triangle to the anterior tubercle region of the tibia. In brief, with the knee in a fully extended position, a skin flap extending from the lower one-third of the anteromedial thigh to a point approximately 5 cm distal to the superior prominence of the tibial tuberosity was reflected. The flap was raised starting from the posterior border of the sartorius and reflected laterally. The saphenous nerve was then identified as it pierced the subsartorial canal and traced distally to identify the IBSN about the knee. Meticulous dissection was used to identify, detail, and mark the distribution patterns of the IBSN about the knee.

Key surgical landmarks (including the medial joint line, tibial tubercle, medial and inferior poles of patella, and Q angle of the limb) were identified and marked with ink. A "Q-angle" line, running from the anterior superior iliac spine through the midpoint of the patella to the tibial tuberosity, was marked to establish the long axis of the limb (this line served as the *y*-axis during digital analysis). The medial joint line of the knee and the most medial and lateral aspects of the patella were identified through the use of fine wire acupuncture needles and marked with black ink. A second line was drawn running perpendicular from the medial joint line of the knee to bisect the Q-angle line below the inferior aspect of the patella (this line served as the *x*-axis during digital analysis). A 1-inch (2.54-cm) marker (to standardize the scale of the image) was then placed on the knee, and digital images were recorded to document the position of the IBSN in relationship to key surgical landmarks.

NIH ImageJ software was used to perform standardized and scaled (using the 1-inch marker as a reference) measurements from the digital images of the position of the IBSN about the *x*-*y* coordinate system. The number and distribution of the IBSN branches were documented about a horizontal line (*x*-axis) positioned along the medial joint line and a vertical line (*y*-axis) running through the tibial tubercle. The intersection point between the joint line and the midline of the lower limb represented the vertex of the triangle. The linear distance was calculated from the vertex of the triangle to the branches of the IBSN at 15°, 30°, 45°, 60°, 75°, and 90° to the horizontal axis (Figure 3). If the branch of the nerve ended before the angle, a distance was not recorded.

Anthropometric measurements and descriptive statistics including mean ± SD, range, and 95% CI were generated for IBSN measurements obtained using the *x*-*y* coordinate system. The percentages of cases with 1, 2, 3, and 4 branches of the IBSN were also determined.

RESULTS

Clinical Study

A total of 37 patients were randomized in this study, 21 (13 women and 8 men) into the OI group and 16 (11 women and 5 men) into the VI group. No statistically significant differences were seen between groups with respect to sex or age. The mean age in the VI group was 29.0 ± 10.5 years; in the OI group, it was 33.4 ± 13.1 years.

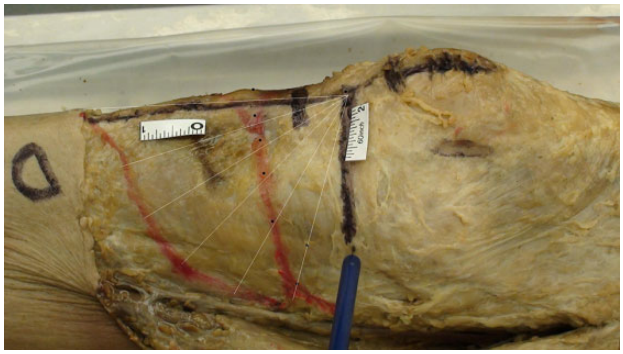

Figure 3. The horizontal line along the medial joint line represents the *x*-axis, and the vertical line through the center of the patella and the tibial tuberosity represents the *y*-axis. The distances from the vertex of the triangle (intersection of *x*- and *y*-axes) to the inferior branch of the saphenous nerve at 15°, 30°, 45°, 60°, and 90° from the *x*-axis were recorded.

TABLE 1
CSA of Altered Skin Sensation in the VI and OI Groups at Each Follow-up Time Point[a]

Time Point, mo	Group	n	CSA, Mean ± SD, cm^2	*P* Value
3	VI	6	45.6 ± 46.1	.57
	OI	5	30.4 ± 37.8	
6	VI	10	58.2 ± 50.1	.08
	OI	10	24.6 ± 31.0	
12	VI	6	53.5 ± 78.4	.65
	OI	10	38.8 ± 48.5	
24	VI	7	48.0 ± 53.1	.27
	OI	10	25.1 ± 30.9	

[a]CSA, cross-sectional area; OI, oblique incision; VI, vertical incision.

Patient postoperative data from 3-, 6-, 12-, and 24-month follow-ups examining the presence or absence of altered sensation on the tibia surrounding or below the incision site indicated that there was no significant difference between the groups. Only a small percentage of patients in either group (26% of OI patients and 15% of VI patients) demonstrated an area of altered sensation that was smaller than 5 cm^2 over the duration of the 24-month follow-up. The presence or absence of hypoesthesia (Table 1) at the 4 time points also did not differ between groups postoperatively (3 months, $P = .57$; 6 months, $P = .08$; 12 months, $P = .65$; 24 months, $P = .27$). Interestingly, the CSA data demonstrated a trend toward the OI group having a smaller area of altered skin sensation at every time point; over the duration of the 24-month follow-up, the mean area of altered sensation in the OI group was 30.1 ± 39.5 cm^2 whereas that in the VI group was 52.2 ± 61.5 cm^2. The ACL

TABLE 2
Between-Group Differences in ACL QoL Score at Each Time Point From Before Surgery to 24 Months After Surgery[a]

Time Point, mo	Group	n	ACL QoL, Mean ± SD	Between-Group *t* Test *P* Value
Before surgery	VI	13	35.8 ± 12.8	.21
	OI	16	30.6 ± 9.6	
3	VI	7	58.2 ± 21.2	.38
	OI	7	47.4 ± 22.6	
6	VI	9	57.0 ± 15.8	.51
	OI	12	63.1 ± 23.4	
12	VI	5	64.9 ± 24.6	.90
	OI	13	63.5 ± 21.1	
24	VI	10	60.7 ± 20.3	.24
	OI	14	71.3 ± 21.6	

[a]ACL QoL, anterior cruciate ligament quality of life; OI, oblique incision; VI, vertical incision.

TABLE 3
Distance From the Inferior Branch of the Saphenous Nerve to a Line Representing an Angle From the Intersection Point Between the *x*-Axis (Medial Joint Line) and *y*-Axis (Midline of the Tibial Tubercle)[a]

	Branch 1		Branch 2		Branch 3		Branch 4	
Angle	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean	95% CI
15°	4.97 ± 1.63	4.16-5.78	6.87 ± 1.41	6.01-7.72	6.93 ± 1.80	4.07-9.79		
30°	3.94 ± 1.47	3.19-4.70	6.12 ± 1.89	5.07-7.17	6.55 ± 1.74	4.72-8.38	6.95	
45°	3.27 ± 1.37	2.56-4.00	6.06 ± 2.05	4.88-7.24	6.18 ± 1.91	4.48-8.19	6.94	
60°	3.04 ± 1.37	2.28-3.80	6.18 ± 2.18	4.51-7.86	7.03 ± 0.72		7.37	
75°	3.06 ± 1.66	1.95-4.18	6.99 ± 2.24	4.64-9.33			8.20	
90°	3.04 ± 2.50							

[a]Mean ± SD values and 95% CIs are expressed in centimeters. Missing values indicate branch of nerve was not present at the respective angle or n ≤ 2.

QoL score demonstrated significant improvements for both the VI and OI groups from pre- to postoperative time periods beginning at 6 months and continuing to 24 months (Table 2). No differences were seen between groups at any study time points.

Cadaveric Study

Anthropometric measurements indicated that the mean distance from the inferior pole of the patella to the joint line was 1.83 ± 0.16 cm and from the joint line to the superior aspect of the tibial tubercle was 1.93 ± 0.17 cm. Table 3 presents data regarding the positioning of each IBSN branch about the *x-y* coordinate system. A large variation in the distribution pattern of IBSN branches was observed. Among the 18 cadaveric specimens, 4 variations in the distribution of IBSN were noted: 18 (100%) had 1 branch, 14 (78%) had 2 branches, 6 (33%) had 3 branches, and 1 (6%) had 4 branches.

DISCUSSION

We found no statistically significant differences in the presence or absence of sensory loss, CSA of sensory loss, or quality of life outcomes based on incision type. Therefore, our hypothesis that there would be a difference in the presence or absence of hypoesthesia or in the affected surface area of sensory loss between the vertical and oblique incision groups was not supported. This is in agreement with a recent systematic review investigating saphenous nerve injury during ACL reconstruction[15,17] but contrary to the results of a more recent meta-analysis.[13] The cadaveric study supported the results of this meta-analysis because it confirmed that a safe zone for the incision angle is unlikely due to the large variability in the number and different angles of branches of the IBSN between cadavers. The prior meta-analysis concluded that although nerve injury cannot be eliminated in all patients, an oblique incision could have the lowest risk of nerve injury.[13]

In 2007, Luo et al[7] showed that the incidence of IBSN injury and CSA were 24% and 8.4 cm^2, respectively, for an oblique incision compared with 65.7% and 48 cm^2, respectively, for a vertical incision. The authors suggested that although a safe zone was not achieved with an oblique incision, the number of branches transected or the extent of transection was less in the OI group compared with the VI group.[7] This was confirmed by an ultrasonographic study on healthy volunteers that indicated a vertical incision had the greatest risk of injury compared with a horizontal and oblique incision.[12] Interestingly, Kjaergaard et al[6] showed no difference in numbness on the anterior

aspect of the tibia when comparing oblique versus vertical incisions. That was a nonrandomized study, but it demonstrated the rate of numbness to be significant in the immediate postoperative period (12 days) at 88%. The area of numbness improved in both groups for up to 1 year.[6] The main difference between the 2 studies was the time between surgery and follow-up (a mean of 14 months in the Luo et al[7] study compared with 12 days and 1 year in the Kjaergaard et al[6] study) and the length of the incision (<3.5 cm and >4.5 cm, respectively). It is possible that the increased length of the incision in the Kjaergaard et al study (by >1 cm) resulted in damage to more branches of the IBSN resulting in no difference between groups. In the current study, the incision length was standardized at 4 cm for both techniques, and no difference between groups was found. It stands to reason that the shorter the incision length, the less the risk of transecting 1 or more branches of the IBSN if multiple branches exist for a given patient. A short, oblique incision was strongly recommended by Pekala et al.[13]

Portland et al[14] showed a difference in nerve injury of 43% compared with 59% using a horizontal versus vertical incision during ACL reconstruction. That report was a case series of 3 surgeons' practices. Although it was a study on bone–patellar tendon–bone graft, not STG, it shed light on the lack of literature on the topic of incision angle for graft harvest. In a retrospective study using quadrupled STG, Papastergiou et al[11] reported a 14.9% incidence of IBSN with an oblique incision and 39.7% with a vertical incision. The authors also concluded that the results were not statistically significant and some patients in the horizontal incision group did not have adequate follow-up. Interestingly, patients with more pronounced sensory disturbances had more follow-up visits and a longer follow-up period. Papastergiou et al[11] recommended that horizontal incisions be used to decrease the risk and extent of damage to the IBSN. It is the opinion of the senior author of the current study that an oblique incision for hamstring harvest may be advantageous to better visualize the gracilis fibrous attachments. Collectively, this information has led to the oblique incision being used as standard practice by surgeons at our center. This decision, and a shorter incision length, were recently supported with a meta-analysis by Pekala et al.[13]

The results of the cadaveric study confirm the high degree of variability in both the course and distribution pattern of the IBSN. Four variations in the distribution of IBSN were noted: 18 (100%) had 1 branch, 14 (78%) had 2 branches, 6 (33%) had 3 branches, and 1 (6%) had 4 branches. These results are comparable with those of Kartus et al,[5] who reported that 25% of specimens examined had only 1 IBSN branch, 62% had 2 branches, 16% had 3 branches, and 1.5% had 4 branches.

Regardless of orientation or angle of inclination, ImageJ plots did not support the existence of an IBSN safe zone when performing an oblique incision during ACL reconstruction. Data suggested that a shorter oblique incision (≤4 cm) may intersect IBSN branches less frequently than vertical or horizontal incisions and therefore supported the assertion of other researchers that the oblique incision offers the potential for a significant reduction in the frequency and/or extent of postoperative hypoesthesia.

The current study had several limitations. Low sample size and high loss to follow-up made it difficult to demonstrate statistical differences where strong trends were observed. All procedures were performed using only STG autograft with an open tendon stripper. This may confound our data due to possible injury of the nerve with the tendon stripper passage, making injury to the IBSN less attributable solely to incision type. As previously discussed, another limitation may have been the length of incision. Some literature has suggested that a decreased incision length (≤3.5 cm) may decrease the area and incidence of IBSN injury in vertical incision.[7] Other studies have specified the use of a 4.5-cm incision. In both groups, the length of the incision was 4 cm, which differs from those previously specified and makes it difficult to directly compare studies. Anecdotally, surgeons at our site, including the senior author of this study, have noted a smaller area of numbness in a small cohort of patients receiving allograft reconstruction who have had smaller incisions because tendon harvest was not required. The impact of incision length may warrant further research.

CONCLUSION

In this study, when comparing a vertical versus an oblique incision for STG harvest in ACL reconstruction, we identified no significant differences with respect to incidence or cross-sectional area of sensory loss due to damage of branches of the IBSN. Furthermore, it was not possible to identify a safe zone that would prevent transection of any nerves branches of the IBSN based on the cadaveric component of this study. The cadaveric component of this research documented the large variability in the location and number of branches of the IBSN, which could explain the large discrepancies between studies investigating various angles of incision. However, vertical incision has never demonstrated superiority over oblique incision.

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