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Can sural nerve injury be avoided in the sinus tarsi approach for calcaneal fracture?

A cadaveric study

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Abstract

There is no consensus regarding the references to determine the exact location of the skin incision to minimize iatrogenic sural nerve injury in the sinus tarsi approach for calcaneal fracture.

The purpose of this cadaveric study was to describe the anatomical course of the sural nerve in relation to easily identifiable landmarks during the sinus tarsi approach and to provide a more practical reference for surgeons to avoid sural nerve injury.

Twenty-four foot and ankle specimens were dissected. The bony landmarks used in the following reference points were the tip of the lateral malleolus (point A), lateral border of the Achilles tendon on the collinear line with point A (point B), posteroinferior apex of the calcaneus (point C), inferior margin of the calcaneus on the plumb line through point A (point D), and tip of the fifth metatarsal base (point E). After careful dissection, the distances of the sural nerve to points A and B in the horizontal direction (lines D1 and D2), points A and C in the diagonal direction (lines D3 and D4), points A and D in the vertical direction (lines D5 and D6), and points A and E in the diagonal direction (lines D7 and D8) were measured.

The median ratio of D1 to D1+D2, D3 to D3+D4, D5 to D5+D6, and D7 to D7+D8 were 0.37 (range, 0.26–0.50), 0.23 (range, 016–0.33), 0.35 (range, 0.25–0.45), and 0.32 (range, 0.20–0.45), respectively.

The distance ratios from this study can be helpful to avoid sural nerve injury during the sinus tarsi approach for calcaneal fractures. Established standard incision may have to be modified to minimize sural nerve injury.

Abbreviations: AB = anastomotic branch to the intermediate dorsal cutaneous nerve, ICC = intraclass correlation coefficient.

Keywords: cadaver, calcaneus, complication, fracture, sinus tarsi approach, sural nerve

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This study was conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Chuncheon Sacred Heart Hospital, Hallym University.

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1. Introduction

Calcaneal fractures are the most common tarsal fractures and represent approximately 2% of all fractures. In particular, displaced intra-articular fractures account for 60% to 75% of calcaneal fractures.[1] In displaced intra-articular calcaneal fractures, the treatment is divided into conservative and surgical management. Although controversy still exists on the best treatment for these disabling injuries, surgical treatment to restore the articulation of the calcaneus is optimal for displaced calcaneus fractures involving the subtalar joint.[2]

Traditionally, open reduction and internal fixation using the extensile lateral approach is commonly preferred in displaced intra-articular fracture of the calcaneus because it provides sufficient exposure of the subtalar joint. Unfortunately, this surgical approach is associated with high incidence of complications, such as wound-related complications and sural nerve injuries.[3–5] There has been interest in the minimally invasive approach for calcaneal fractures to reduce these complications, and the sinus tarsi approach has become one of the more popular small incision methods, as it provides direct visualization of the posterior articular facet and has fewer wound-related complications.[6,7]

The sural nerve is vulnerable to injury during the initial incision in both the sinus tarsi and the extensile lateral approaches, although the occurrence of sural nerve injuries is reportedly lower in the former.[8–10] In addition, intraoperative damage to the sural nerve is critical because it affects a patient's prognosis. Most surgeons seem to recognize the course of the sural nerve and its risk of injury during the sinus tarsi approach. However, there is no consensus regarding the references to determine the exact location of the skin incision in this approach.

The purpose of this cadaveric study was to describe the anatomical course of the sural nerve in relation to easily identifiable landmarks within the operative area during the sinus tarsi approach for calcaneal fractures and to provide a more practical reference for surgeons to make an optimal incision to avoid sural nerve injury.

2. Materials and methods

This study was approved by the Ethics Committee of our institution (Chuncheon Sacred Heart Hospital, Hallym University).

Twenty-four isolated (10 left and 14 right) foot and ankle specimens in adult formalin-fixed cadavers were dissected. Of the 24 specimens, 12 (50%) were from female and 12 (50%) from male cadavers and all specimens were unilateral. The mean age of the donors at death was 72.1 (range, 52–91) years. The lateral aspect of the foot of all cadavers demonstrated intact skin and no signs of previous trauma or surgery, obvious deformities, and/or ulcers.

The foot and ankle specimens were stabilized in the lateral position, and the following five reference points on the skin were identified by palpation and marked before dissection: point A, the tip of the lateral malleolus; point B, the lateral border of the Achilles tendon on the collinear line with point A; point C, the posteroinferior apex of the calcaneus; point D, the inferior margin of the calcaneus on the plumb line through point A; point E, the tip of the 5th metatarsal base (Fig. 1).

A section of the skin was meticulously dissected from the lateral side of the ankle and hindfoot. The posterior inferior margin of the skin dissection was started at the most inferior and posterior point of the calcaneus. This dissection approach allowed adequate visualization of the sural nerve, including the main trunk of the sural nerve, the lateral calcaneal branches, and the anastomotic branch to the intermediate dorsal cutaneous nerve (AB).

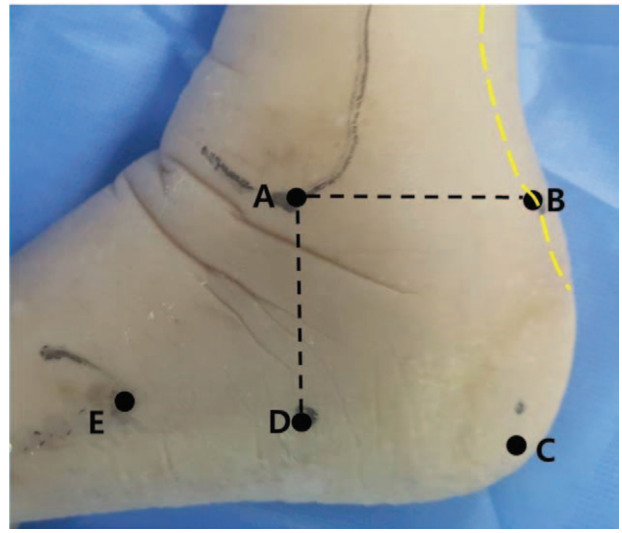

Figure 1. Five reference points on the skin marked before dissection. A, the tip of the lateral malleolus; point B, the lateral border of the Achilles tendon (yellow dot line) on the collinear line with point A; point C, the posteroinferior apex of the calcaneus; point D, the inferior margin of the calcaneus on the plumb line through point A; and point E, the tip of the 5th metatarsal base.

Following careful dissection, the distances of the sural nerve to points A and B in the horizontal direction (lines D1 and D2, respectively), points A and C in the diagonal direction (lines D3 and D4, respectively), points A and D in the vertical direction (lines D5 and D6, respectively), and points A and E in the diagonal direction (lines D7 and D8, respectively) were measured. In the absence of the AB, the distance of the main trunk of the sural nerve to points were measured (Fig. 2A), whereas the distance of the AB to points were measured in the presence of the AB (Fig. 2B). The identification of landmarks and measurements of the distances were performed by two independent researchers, who each repeated the landmark identification

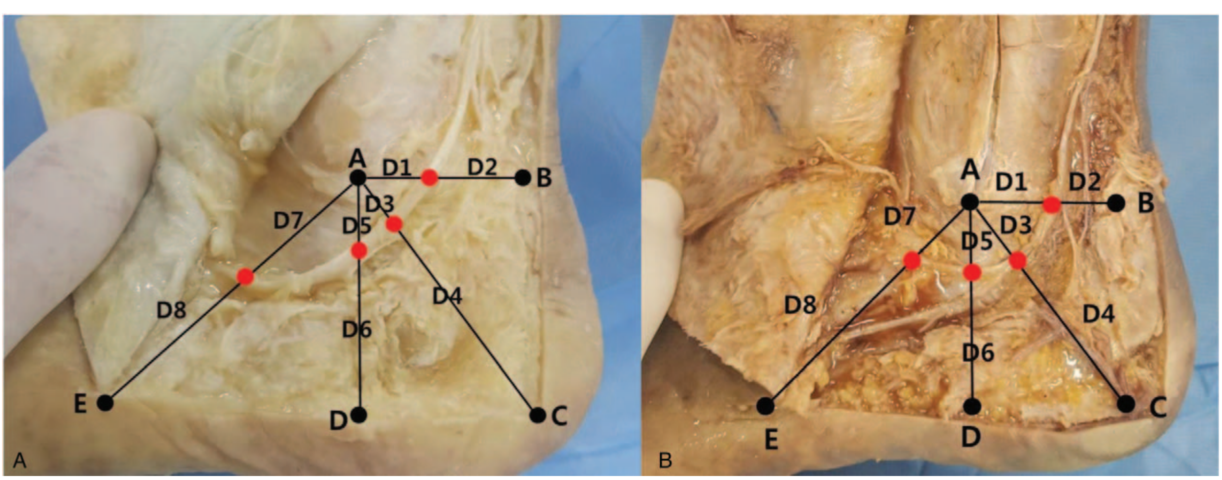

Figure 2. Distances were measured. (A) Absence of an an anastomotic branch to the intermediate dorsal cutaneous nerve, (B) presence of an an anastomotic branch to the intermediate dorsal cutaneous nerve. Line D1, the horizontal distance between point A and the nerve; line D2, the horizontal distance between point B and the nerve; line D3, the diagonal distance between point A and the nerve; line D4, the diagonal distance between point C and the nerve; line D5, the vertical distance between point A and the sural nerve; line D6, the vertical distance between point D and the nerve; line D7; the diagonal distance between point A and the nerve; and line D8, the diagonal distance between point E and the nerve.

and distance measurements twice. The averages of the two researchers' measurements were recorded to describe each specimen.

Interobserver and intraobserver reliabilities were obtained for all measurements using the intraclass correlation coefficient (ICC). According to the definitions of Landis and Koch,[11] ICCs of 0.81 to 1.00, 0.61 to 0.80, 0.41 to 0.60, 0.21 to 0.40, and 0.00 to 0.20 were interpreted as excellent, good, moderate, fair, and poor, respectively. To evaluate the central tendency of all specimens, each distance (from D1 to D8) was presented using the median and range. Since the number of specimens was less than 30, it was not applicable to the normality assumption. Therefore, the median and range according to the nonparametric method were used. Additionally, the ratios of D1 to D1+D2 (R1), D3 to D3+D4 (R3), D5 to D5+D6 (R5), and D7 to D7+D8 (R7) were calculated, and each ratio was also presented as the median, range, and interquartile range. The Wilcoxon–Mann–Whitney test was performed to compare the ratio between sexes. The studies were compared pair-wise by Student's *t* test method since only summary statistics of reference paper were available. To solve the multiple testing problems, the *P* value was adjusted by using the Bonfferoni correction method. All statistical analyses were performed using the SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY). A *P* value less than .05 was considered statistically significant.

3. Results

Intraclass correlation coefficients were generated for all measurements. All measurements were higher than 0.80 (indicating acceptable reliability) and were employed in the study. The median values, ranges, and interquartile ranges for all distances measured between the sural nerve and the selected reference landmarks are listed in Table 1. Mean values and standard deviations were also provided to help compare with the distances reported in previous studies. The median ratio of D1 to D1+D2 (R1), D3 to D3+D4 (R3), D5 to D5+D6 (R5), and D7 to D7+D8 (R7) were 0.37 (range, 0.26–0.50), 0.23 (range, 0.16–0.33), 0.35 (range, 0.25–0.45), and 0.32 (range, 0.20–0.45), respectively. The median values, ranges, and interquartile ranges for all ratios are also represented in a box plot (Fig. 3). There was no significant difference in all ratios by sex ($P = .17$ [R1], .47 [R3], .84 [R5], and .23 [R7], respectively).

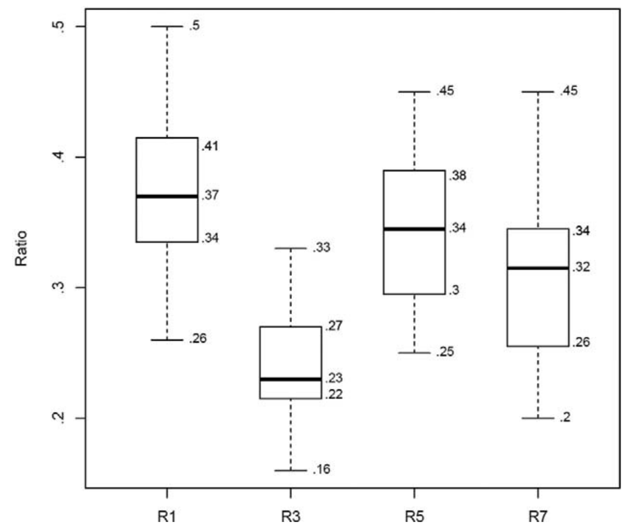

Figure 3. Box plot of the all ratios (Number = 24 specimens). The boxes represent the interquartile ranges; the horizontal lines within the boxes represent the median values; and the lines outside the boxes represent the ranges. R1, ratio of D1 to D1+D2; R3, ratio of D3 to D3+D4; R5, ratio of D5 to D5+D6; R7, ratio of D7 to D7+D8.

4. Discussion

Open reduction and internal fixation has been recommended as an appropriate treatment for displaced intra-articular calcaneal fractures for several decades.[2] However, surgical treatment is accompanied by high rates of complications, including wound-related complications (7.57%–32.8%) and neurovascular injuries (9.1%–25%).[2,12–15] The most widely used surgical approach for calcaneal fractures is the extensile lateral approach, despite its fairly high rates of wound-related complications and sural nerve injuries.[3–5] To minimize the risk of operative complications, various minimally invasive approaches have been described, and the sinus tarsi approach has become increasingly popular among surgeons.[16] The sinus tarsi approach has been reported to have significantly fewer wound-related complications than the extensile lateral approach.[6,7,10,17] However, although its rate of sural nerve complication is lower that the extensile lateral approach, there is no significant difference.[8–10]

Table 1

The distances measured between the sural nerve and the selected reference land-marks. (Number = 24 specimens).

Distance (mm)	Median	Range min	Range max	IQR Q1	IQR Q3	Mean	SD
D1	15.00	8.00	24.00	12.25	18.75	15.46	4.27
D2	27.00	13.00	39.00	20.50	30.00	25.63	6.41
D3	13.00	9.00	18.00	11.25	14.00	13.04	2.58
D4	41.00	27.00	53.00	36.25	44.75	41.08	6.38
D5	14.00	10.00	21.00	12.00	17.75	14.50	3.51
D6	27.50	21.00	32.00	24.25	30.00	27.25	3.38
D7	19.00	11.00	29.00	13.00	20.75	18.21	4.97
D8	40.50	30.00	50.00	38.00	43.50	40.25	5.50

Distance: D1 = the horizontal distance between point A and the nerve, D2 = the horizontal distance between point B and the nerve, D3 = the diagonal distance between point A and the nerve, D4 = the diagonal distance between point C and the nerve, D5 = the vertical distance between point A and the sural nerve, D6 = the vertical distance between point D and the nerve, D7 = the diagonal distance between point A and the nerve, D8 = the diagonal distance between point E and the nerve, IQR = interquartile ranges, Q1 = lower quartile, Q3 = upper quartile, SD = standard deviation.

Although sural nerve-related problems postoperatively are less common compared to wound-related complications, these injuries are important as they affect the surgical outcome and prognosis. Intraoperative damage to the sural nerve could cause paresthesia or anesthesia along the lateral border of the foot and could occasionally form painful neuromas that are difficult to treat. Transection of the peripheral nerve naturally leads to the formation of a terminal neuroma, over 30% of which are painful. Additionally, the rate of painful neuromas is even higher in superficial sensory nerves.[18] The sural nerve runs superficially on the lateral aspect of the calcaneus.[19] Thus, anatomically, it is easily damaged not only during skin incision, but also during subsequent dissection, reduction of fracture, and suturing, if an inappropriate incision has been made.

In our study, we hypothesized that identification of the course of the sural nerve in accordance with easily identifiable bony landmarks may minimize the risk of sural nerve injury during the sinus tarsi approach for calcaneal fracture. We used the lateral malleolus, Achilles tendon, margin of the calcaneus, and fifth metatarsal bone as anatomical reference points. In previous studies,[20,21] the mean vertical distance between the tip of the lateral malleolus and the sural nerve was reported as 13.15 ± 6.88 and 13 ± 7 mm, respectively, compared with 14.5 ± 3.5 mm in our study. These differences in values were not statistically significant compared with the Student's *t* test and adjusted through Bonferroni correction method. (reference 20 vs our study; $P = .53$, reference 21 vs our study; $P = .27$) This may have been contributed by the size of the cadavers and the variability of the nerve course. In addition, the distribution of the residual value of the ratio was less than the distribution of the residual value of the distance, when the statistical residual values of the mean value of the distance and the mean value of the ratio were compared. We therefore determined that it would be more reliable and clinically useful to describe the ratio rather than the absolute distance. Figure 3 shows the minimum of the ratios (R1, R3, R5, and R7) approximates to 0.26, 0.16, 0.25, and 0.20, respectively. Using these minimum ratio values through reference landmarks based on the tip of the lateral malleolus prior to surgical incision, we hypothesized that an incision for sural nerve preservation could be established during the sinus tarsi approach. In particular, the distal tip of the fibula and the base of the fifth metatarsal were considered to be anatomical landmarks that could assist in predicting the sural nerve's course, although calcaneal landmarks could be difficult to identify due accompanying intra-articular involvement and comminuted morphology.

To date, the established standard incision for the sinus tarsi approach to the calcaneus (as described in the literature) is by creating a straight longitudinal line from the tip of the distal fibula and extending toward the base of the fourth metatarsal.[7–10,16] Using this incision, Weber et al[9] noted that there was no sural nerve-related symptoms, although the number of patients in that study was limited to 24. Further evidence of postoperative sural nerve-related symptoms following the sinus tarsi approach among a larger number of patients have been found, with Kline et al,[8] Yeo and Kwek,[10] Zhang et al,[16] and Li[22] reporting an incidence of 3%, 5%, 4.2%, and 9.6%, respectively. These results may be attributed to the fact that not only the main trunk injury of the sural nerve but also the injury of the AB could be included in the distal extent of the standard incision for sinus tarsi approach.

An anatomical study that analyzed the distribution pattern of the sural nerve in 110 Korean cadavers analogized that 58.8% of the cadavers had the possibility of involvement of the AB of the sural nerve in the range of the standard incision for the sinus tarsi approach.[19] Our results showed that the AB of the sural nerve was present in 15 specimens (62.5%) (Fig. 2B). Thus, recognition of the potential presence of the AB at incision during the sinus tarsi approach may be important in preventing intraoperative sural nerve-related symptoms.

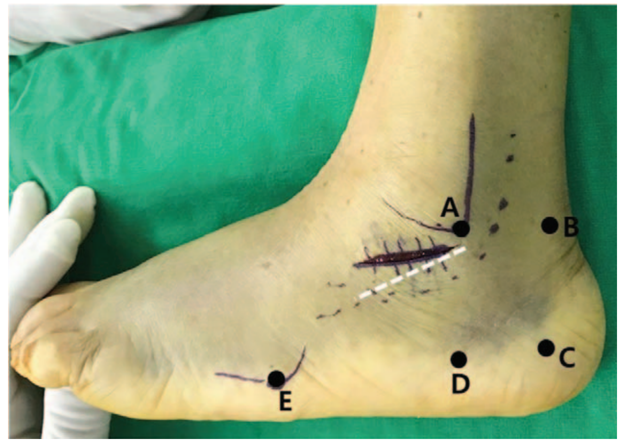

Figure 4. After drawing the expected course of the sural nerve using the distance ratios in accordance with bony landmarks, the modified incision line was made distally from just distal to the tip of the fibula to the level of the calcaneocuboid joint and almost horizontal to the sole of the foot. The established standard incision (white colored dotted line) crossed a major branch of the sural nerve.

Additionally, according to cadaveric study, the sural nerve is usually anastomosed to the superficial peroneal nerve at the base of the fourth metatarsal.[19] A recent clinical study reported that a major branch of the sural nerve was directly under the standard incision in nearly 70% of cases.[22] Our results demonstrated that a standard incision (measuring 4–5 cm in length made from the tip of distal fibula to the base of the fourth metatarsal) was no longer safe to prevent sural nerve damage in the sinus tarsi approach, and established standard incision may need to be modified to minimize sural nerve injury. Therefore, we suggest that it is preferable and safer to make a straight incision distally from just distal to the tip of the fibula to the level of the calcaneocuboid joint and almost horizontal to the sole of the foot. In addition, the modified incision proposed would be anatomically sufficient to provide adequate exposure to accomplish successful reduction and fixation of calcaneal fractures (Fig. 4).

The results of this study could be applied to incision for sinus tarsi approach regardless of sex. However, its small sample size may have weakened the statistical power with regards to the possibility of sural nerve variations. Larger samples are necessary in future studies to allow for a more accurate description of the sural nerve. To clinically apply the results of this study, a validation study using a larger number of cadavers is required. Also, the bilateral difference could not be evaluated because all specimens in our study were unilateral. Therefore, future studies should include an evaluation of the bilateral difference.

5. Conclusions

In conclusion, the distance ratios presented in this cadaveric study can be helpful to describe the course of the sural nerve in accordance with easily identifiable bony landmarks, thus avoiding sural nerve injury, during the sinus tarsi approach for calcaneal fractures. Furthermore, these results would be more practical references for surgeons to minimize sural nerve injury. We found that the established standard incision that has been used in the sinus tarsi approach may be no longer safe in preventing sural nerve injury. Careful planning using modified incision will help minimize sural nerve injury during the sinus tarsi approach.

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References

[1] Lesić AR, Atkinson HD, Bumbasirević V, et al. Calcaneal fractures—the orthopaedic challenge. Acta Chir Iugosl 2012;59:33–9.
[2] Sanders R. Displaced intra-articular fractures of the calcaneus. J Bone Joint Surg Am 2000;82:225–50.
[3] Al-Mudhaffar M, Prasad CV, Mofidi A. Wound complications following operative fixation of calcaneal fractures. Injury 2000;31:461–4.
[4] Benirschke SK, Kramer PA. Wound healing complications in closed and open calcaneal fractures. J Orthop Trauma 2004;18:1–6.
[5] Harvey EJ, Grujic L, Early JS, et al. Morbidity associated with ORIF of intra-articular calcaneus fractures using a lateral approach. Foot Ankle Int 2001;22:868–73.
[6] Hospodar P, Guzman C, Johnson P, et al. Treatment of displaced calcaneus fractures using a minimally invasive sinus tarsi approach. Orthopedics 2008;31:1112.
[7] Schepers T. The sinus tarsi approach in displaced intra-articular calcaneal fractures: a systematic review. Int Orthop 2011;35:697–703.
[8] Kline AJ, Anderson RB, Davis WH, et al. Minimally invasive technique versus an extensile lateral approach for intra-articular calcaneal fractures. Foot Ankle Int 2013;34:773–80.
[9] Weber M, Lehmann O, Sagesser D, et al. Limited open reduction and internal fixation of displaced intra-articular fractures of the calcaneum. J Bone Joint Surg Br 2008;90:1608–16.
[10] Yeo QY, Kwek EB. Open reduction and internal fixation of displaced intra-articular calcaneal fractures with Norian Skeletal Repair System (SRS) bone cement: surgical technique, clinical and radiographical results. Ann Acad Med Singapore 2014;43:515–6.
[11] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[12] Abidi NA, Dhawan S, Gruen GS, et al. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures. Foot Ankle Int 1998;19:856–61.
[13] Buckley RE, Meek RN. Comparison of open versus closed reduction of intraarticular calcaneal fractures: a matched cohort in workmen. J Orthop Trauma 1992;6:216–22.
[14] Folk JW, Starr AJ, Early JS. Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. J Orthop Trauma 1999;13:369–72.
[15] Paley D, Fischgrund J. Open reduction and circular external fixation of intraarticular calcaneal fractures. Clin Orthop Relat Res 1993;4:125–31.
[16] Zhang T, Su Y, Chen W, et al. Displaced intra-articular calcaneal fractures treated in a minimally invasive fashion: longitudinal approach versus sinus tarsi approach. J Bone Joint Surg Am 2014;96:302–9.
[17] Li LH, Guo YZ, Wang H, et al. Less wound complications of a sinus tarsi approach compared to an extended lateral approach for the treatment of displaced intraarticular calcaneal fracture: a randomized clinical trial in 64 patients. Medicine (Baltimore) 2016;95:e4628.
[18] Koch H, Hubmer M, Welkerling H, et al. The treatment of painful neuroma on the lower extremity by resection and nerve stump transplantation into a vein. Foot Ankle Int 2004;25:476–81.
[19] Jeon SK, Paik DJ, Hwang YI. Variations in sural nerve formation pattern and distribution on the dorsum of the foot. Clin Anat 2017;30:525–32.
[20] Aktan Ikiz ZA, Uçerler H, Bilge O. The anatomic features of the sural nerve with an emphasis on its clinical importance. Foot Ankle Int 2005;26:560–7.
[21] Solomon LB, Ferris L, Tedman R, et al. Surgical anatomy of the sural and superficial fibular nerves with an emphasis on the approach to the lateral malleolus. J Anat 2001;199(Pt 6):717–23.
[22] Li S. Wound and sural nerve complications of the sinus tarsi approach for calcaneus fractures. Foot Ankle Int 2018;39:1106–12.