Observational Study

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Two-team-approached free flap reconstruction for plantar malignant melanoma

An observational (STROBE-compliant) trial

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Abstract

Reconstructive treatments of heel defects usually involve regional flap techniques such as medial plantar flap procedures due to the limited availability of adjacent soft tissues. Although free flaps have advantages in terms of function and aesthetics, they remain challenging due to the longer operation time required than for regional flaps. Thus, we introduce an appropriate 2-team surgical protocol to reconstruct plantar defects after wide excision of malignant melanoma using free flap coverage.

From 2015 to 2020, a retrospective study was performed including 21 patients who underwent free flap surgeries to reconstruct defects due to plantar malignant melanoma. Lymphoscintigraphy was performed to localize sentinel lymph nodes, and the procedure was carried out by 2 teams working together, a tumor-ablative team and a reconstructive team. The present study is adhered to the STROBE guidelines for cohort studies.

The average operation time was 241.4 minutes and was not significantly different even in cases with inguinal dissection (*P* value: 0.641). All flaps survived after 2 cases of venous insufficiency and 1 case of hematoma were resolved by immediate revision surgery.

The 2-team approach to surgically reconstruct heel defects after wide excision of malignant melanoma using free flap coverage offers favorable results and lower morbidity than regional flap approaches.

Abbreviations: ALT = anterolateral thigh, CT = Computed tomography, NCCN = National comprehensive cancer network, PET = Positron emission tomography, SD = Standard deviation, SLN = sentinel lymph nodes, STROBE = Strengthening the reporting of observational studies in epidemiology.

Keywords: free tissue flaps, melanoma, protocol, reconstructive surgical procedures

1. Introduction

Malignant melanoma is a cancer derived from melanocytes that are found predominantly in the skin.[1] Although it accounts for only 4% of all skin cancers, it has significantly higher morbidity and mortality, causing 80% of all skin cancer deaths with only 14% of patients achieving 5-year survival.[2–4] Malignant melanoma of the foot accounts for 3% to 15% of all melanomas,[5–7] but has higher recurrence (16%–37%) due to its aggressive nature than other cutaneous malignant melanomas.[5,6,8,9]

Surgical resection with adequate margins provides the best chances of long-term survival and progression-free survival.[10,11] However, because wide excision of melanoma yields large defects, soft tissue coverage of the heel needs to withstand high loading pressures and shear forces. The provision of durable and safe weight-bearing surfaces permit normal ankle motion[12,13] and allows patients to wear shoes.[14] Thus, the reconstruction of oncologic foot defects is an indispensable part of the treatment of malignant melanoma.[15]

Reconstructive treatments using similar tissue from the same foot including medial plantar flaps[16–18] and reverse sural flaps[19–21] are good options, but are limited by the lack of adjacent soft tissues, flap size, arc of rotation, and subsequent donor morbidity in the plantar region. Therefore, it is often necessary to perform skin grafts or flap coverage.[22,23] Free muscle flaps, including latissimus dorsi and gracilis muscle flaps with skin grafts, have also been suggested.[24,25] Although such an approach supplies sufficient soft-tissue volume to obliterate dead spaces and defects,[26–28] the resulting

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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wounds require secondary debulking procedures and lead to skin problems including hypertrophic scarring and ulcerative lesions.[29,30]

Thus, free flap approaches are useful reconstruction choices for salvage treatment of the foot and ankle.[31,32] Fasciocutaneous free flaps provide ample volume supply and satisfactory outcomes functionally and aesthetically,[23] but the reconstruction of oncologic foot defects using fasciocutaneous perforator flaps is rare and the outcomes of such surgery remain poorly elucidated.[15,33]

In the present study, we suggest a 2-team surgical protocol to reconstruct plantar defects using simultaneous free flap coverage that offers short operation time and good functional results.

2. Patients and Methods

From June 2015 to June 2020, we performed a retrospective study including 21 patients who underwent free flap reconstructions of defects due to plantar malignant melanoma. A multi-disciplinary team of clinicians treating malignant melanoma at Seoul St. Mary's Hospital, including members of the departments of plastic surgery, oncology, dermatology, pathology, nuclear medicine, and radiation oncology, performed surgery and administered treatment methods including chemotherapy, immunotherapy, and radiation therapy. Our study was approved by the Institutional Review Board (Catholic Medical Center Office of Human Research Protection Program). The patients included 16 males and 5 females, and their average age was 67.7 years (range, 52–88 years). The mean follow-up time was 18.0 months.

Malignant melanoma was confirmed by preoperative punch biopsy or incisional biopsy, and simultaneous tumor excision and plantar reconstruction were planned after distant metastasis was excluded through PET CT. The safety margin of wide excision was 1-3 cm, depending on the depth of invasion according to NCCN guidelines.[34] Immediate reconstruction at the time of tumor ablation was performed with contralateral free anterolateral thigh (ALT) flaps.

Handheld Doppler mapping and lower extremity angiography or computed tomographic angiography were performed to evaluate the vascular status of the extremity and to localize recipient vessels for potential donor flaps. Cutaneous perforators of the ALT flap on the contralateral side were traced by handheld Doppler. The ALT flap was centered over the location of the traced vessels and its long axis was designed to run parallel to that of the thigh.

On the day of surgery, lymphoscintigraphy was performed to localize sentinel lymph nodes (SLN). The 2 teams completed their respective roles in all cases. As shown in the flow sheet in Fig. 1, surgical cooperation was governed according to the position of the SLN. Team A, the oncological surgery team, handled tumor excision, prepared recipient vessels near the defect, and closed the donor site. Team B, the reconstruction team, simultaneously harvested the contralateral ALT flap, microscopically anastomosed vessels, and closed the recipient sites. Operation time was defined as the duration of surgery from first incising the skin to finishing closure. Meanwhile, the operating fields were clearly distinguished between team A and team B to thoroughly prevent cancer cell contamination, and separate surgical instruments and scrub nurse teams were assigned to each of the 2 teams.

3. Flow on the day of surgery

3.1. SLN in popliteal region

The patient was placed in prone position, which allowed team A to excise the malignant melanoma while team B excised the popliteal SLN. After confirming the negative frozen biopsy of the malignant melanoma on all margins and SLN, the patient was changed to a supine position. At the same time, team B harvested the ALT flap according to defect size while team A

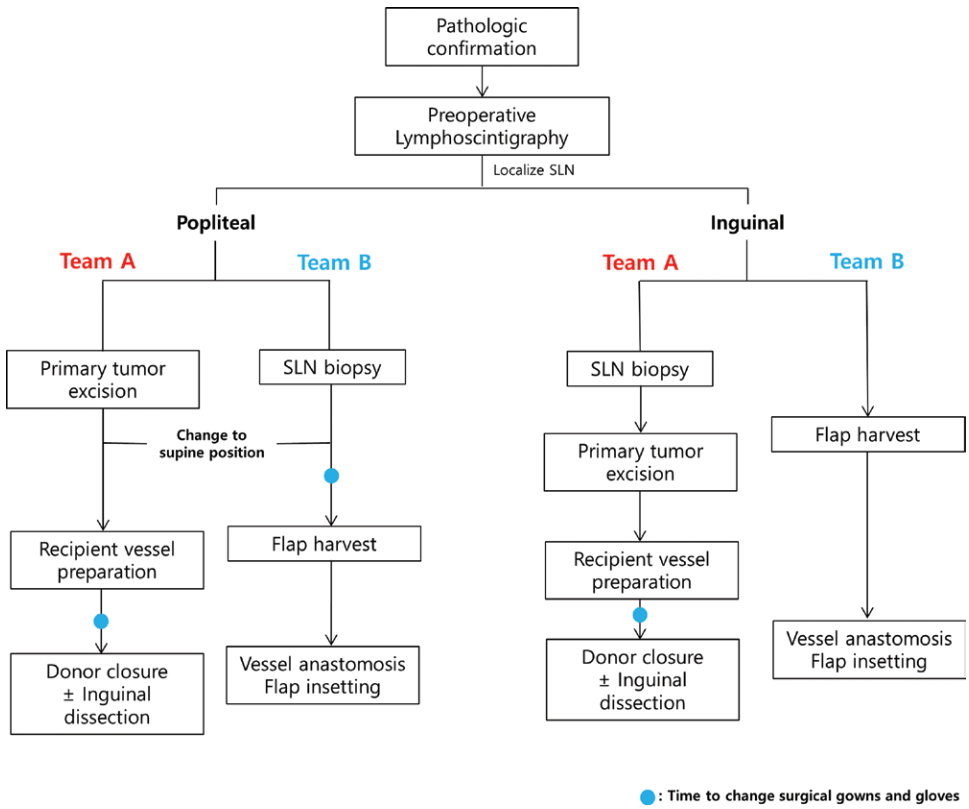

Figure 1. Flow chart of surgical protocol with the 2-team approach. Abbreviation: SLN, sentinel lymph nodes.

prepared the recipient vessels. Team B then inset the ALT flap in the defect and anastomosed the vessels under microscopic view, and team A sutured the donor site.

3.2. SLN in the inguinal region

The patient was placed in supine position, which allowed team B to elevate the ALT flap according to the expected defect size while team A excised the inguinal SLN and excised the malignant melanoma while maintaining the safety margin. After confirming the negative marginal frozen biopsy of the malignant melanoma, team A prepared the recipient vessels. Team B then inset the ALT flap in the defect and anastomosed the vessels under microscopic view, and team A sutured the donor site.

3.3. Positive SLN

In cases of inguinal dissection of positive SLNs, after the SLN was confirmed positively by frozen biopsy, team A usually dissected the inguinal lymph nodes while team B reconstructed the defect of the heel.

4. Postoperative Management

Postoperative management included aspirin for 3 weeks with prostaglandin for 1 week followed by beraprost for 3 weeks as described previously.[35] The flap was monitored every hour for the postoperative first day, every 2 hours up to the second day, and every 4 hours up to the fifth day by assessing the color, temperature, capillary refill rate, skin tension and turgor of flap and Doppler sound for pedicle flow.

Patients who had stable flap status after postoperative 3 weeks were allowed to start gradual weight bearing with a cast applied from the tenth day after surgery. Then, weight bearing on crutches was initiated without the cast by 3 weeks and full weight bearing was allowed by 4 weeks if there were no additional problems with the bone or reconstructed flap. After discharge, patients were examined every 6–12 months by complete blood count test, chest x-ray, chest CT, and positron emission topography scan. If any lymph nodes or distant metastases were detected during the surveillance period, chemotherapy or immunotherapy was added to the treatment protocol.

5. Statistical Analyses

For continuous variables presenting a Gaussian distribution, the mean and SD were used for description, the difference between groups was compared using unpaired *t*-test. For nominal variables, fractions in percentages were calculated, and Fisher exact test and Chi-square test were used for comparison. A P value <0.05 indicated a statistically significant difference.

6. Results

The baseline characteristics and demographic data of the patients are summarized in Table 1. Most SLNs were located in the inguinal area (19 cases, 90.5%), and ten SLNs (47.6%) were positive on frozen biopsy following inguinal dissection. The mean size of soft tissue defects was 52.0 ± 21.0 cm^2 (range, 5 × 6 cm to 10 × 10 cm), and of flaps was 82.5 ± 36.9 cm^2 (range, 5 × 6 cm to 13 × 10 cm) (Table 2).

The mean operation time was 241.4 ± 66.7 minutes (range, 165–420). The mean time for cases with dissection of inguinal lymph nodes was 251.9 ± 77.9 minutes (range, 165 to 420), while it was 231.9 ± 56.8 minutes (175–380) for cases without inguinal dissection. The differences were not statistically significant regardless of whether inguinal dissection was added (P value: 0.

Table 1

Patient characteristics and demographics.

Variables	Values
Age	67.7 ± 12.2
Sex	
Male	16 (76.2%)
Female	5 (23.8%)
BMI	23.9 ± 2.9
Smoking history	
Yes	9 (42.9%)
No	12 (57.1%)
Underlying diseases*	
Yes	16 (76.2%)
No	6 (23.8%)
Tumor side	
Right	10 (47.6%)
Left	11 (52.4%)
SLN location	
Inguinal	19 (90.5%)
Popliteal	2 (9.5%)
Clark level	
In situ	2 (9.5%)
I	0 (0.0%)
II	2 (9.5%)
III	2 (9.5%)
IV	10 (47.6%)
V	5 (23.8%)
Clinical stage	
0	1 (4.8%)
IA	4 (19.0%)
IB	4 (19.0%)
IIA	1 (4.8%)
IIB	3 (14.3%)
IIC	2 (9.5%)
III	5 (23.8%)
IV	1 (4.8%)

*Underlying diseases include: hyperthyroidism, benign prostate hyperplasia, diabetes mellitus, hypertension, rheumatoid arthritis, dyslipidemia, lung tuberculosis, Parkinson disease, prostate cancer, arrhythmia, gout, and hypothyroidism.
Abbreviation: SLN, sentinel lymph node.

Table 2

Surgical outcomes.

Variables	Values
Operation time (min)	241.4 ± 66.7
Blood loss (mL)	108.1 ± 69.8
Hospital stay (d)	15.3 ± 6.4
Follow up periods (mo)	18.0 ± 11.4
Inguinal dissection	
O	10 (47.6%)
X	11 (52.4%)
Recipient artery	
PTA	14 (66.7%)
ATA	3 (14.3%)
DPA	2 (9.5%)
Metatarsal artery	2 (9.5%)
Defect size (cm^2)	52.0 ± 21.0
Flap size (cm^2)	82.5 ± 36.9
Early complications	3 (14.3%)
Venous insufficiency*	2 (9.5%)
Hematoma*	1 (4.8%)
Late complications	2 (9.5%)
Marginal disruption	1 (4.8%)
Lymphedema†	1 (4.8%)

*Each early complication was resolved by the immediate revisional operation.
† One lymphedema occurred after the inguinal dissection.
Abbreviations: ATA = anterior tibial artery, DPA = dorsalis pedis artery, PTA = posterior tibial artery.

641) (Table 3, Fig. 2). The average duration of hospital stay for all cases was 15.3 ± 6.4 days. That for cases with dissection of inguinal lymph nodes was 16.4 ± 7.1 days and without inguinal dissection was 14.4 ± 5.8 days. These differences were not statistically significant (*P* value: 0. 498). The mean operation time of 19 cases with inguinal SLNs was 224.7 ± 42.5 minutes, while that of 2 cases with popliteal SLNs was 400.0 ± 28.3 minutes. This difference was significant (*P* value: 0.010) (Table 4).

All flaps survived after 2 cases of venous insufficiency and 1 case of hematoma were resolved by immediate revision surgery. One case of lymphedema occurred after inguinal dissection, and 1 marginal disruption occurred. Regional recurrences occurred in 2 cases, and distant metastases occurred in 3 cases (Table 5).

None of these patients needed an orthosis for walking. After surgery, 4 patients underwent debulking with liposuction and skin resection. At this time, the skin was removed outside the weight-bearing zone so that the incision line did not interfere with walking. All these procedures were performed in an outpatient clinic under local anesthesia, and patients were allowed to walk normally from 2 days after surgery. In 1 patient, there was shearing on the flap surface, and it healed only with dressing within 2 weeks of onset.

7. Case Reports

7.1. Case I

A 71-year-old female was referred to our clinic with a 2-cm protruding malignant melanoma diagnosed by histologic analysis of a biopsy at her right plantar heel, which had enlarged during a 1-year period (Fig. 3A). After lymphangiography revealed that SLN was in the inguinal site (Fig. 4A), team B excised the SLN. After frozen biopsy it was confirmed to be positive. A tumor-free defect measuring 7 × 6 cm remained after wide excision by team A with 2.0 cm of free margin that contained the plantar fascia (Fig. 3B). A 12 × 6-cm free ALT flap was harvested by team B from the contralateral area with a 9-cm pedicle. The dorsalis pedis and its venae comitantes were prepared by team A as recipient vessels and connected by team B using end-to-side anastomosis (Fig. 3C). At the same time, team A performed inguinal lymph node resection (Fig. 4B & 4C), but the Cloquet node was negative on frozen biopsy. The operation time was 240 minutes. The flap survived without postoperative complications and the donor site healed uneventfully. The patient received 6 sessions of interferone therapy. She was able to walk and run without developing ulcers and without relapse of the malignant melanoma of the heel 39 months postoperatively.

Table 3

Comparisons of operation times and hospital stay according to inguinal dissection.

Variables	Values	*P*-value
Operation time (min)		0.641
Performed inguinal dissection	251.9 ± 77.9	
Not performed	231.9 ± 56.8	
Hospital stay (d)		0.498
Performed inguinal dissection	16.4 ± 7.1	
Not performed	14.4 ± 5.8	

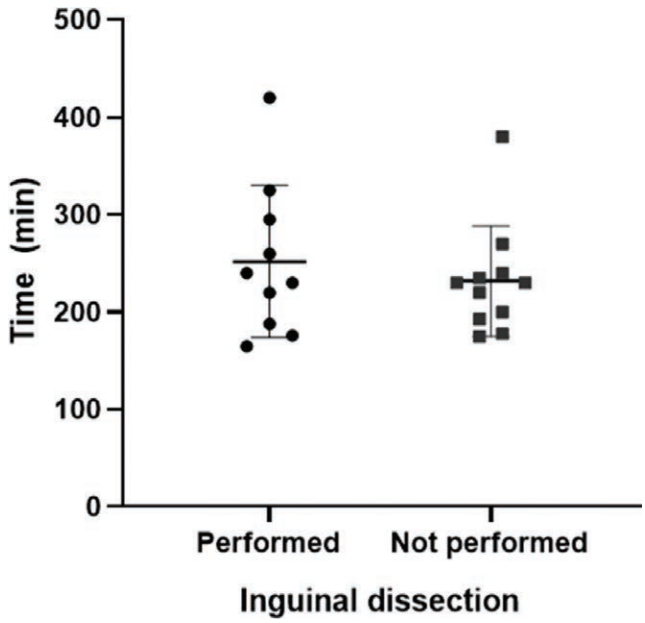

Figure 2. Differences in operative time difference according to inguinal dissection.

7.2. Case II

A 64-year-old male was referred to our clinic with a Clark level II malignant melanoma on his right plantar heel that had occurred 2 years prior (Fig. 5A). Upon lymphangiography, SLN was located in the popliteal region (Fig. 6A) and was excised with the patient in the prone position by team B at the beginning of the surgery (Fig. 6B & 6C). The biopsy was negative, and inguinal lymph node resection was not necessary. At the same time, the tumor-free defect created through wide excision by team A with 2.0 cm of free margin contained the plantar fascia and was 7 × 8 cm (Fig. 5B). After the patient was changed to supine position, a 17 × 10-cm free ALT flap was harvested by team B from the contralateral area with a 10-cm pedicle. The posterior tibial artery and its 2 venae comitantes were dissected by team A as recipient vessels and connected by team B by end-to-side anastomosis (Fig. 5C) while team A closed the donor site. The operation time was 380 minutes. The flap survived without postoperative complications and the donor site healed uneventfully without any chemotherapy. No developing ulcers, relapse of malignant melanoma, or distant metastasis were investigated during 21 months of follow-up.

Table 4

Comparison of operation time according to location of sentinel lymph node.

Variables	Values	*P* value
Operation time (min)		
Inguinal SLN	224.7 ± 42.5	0.010*
Popliteal SLN	400.0 ± 28.3	

Abbreviation: SLN, sentinel lymph node.

**P*-value less than 0.05 indicated a statistically significant difference.

Table 5

Prognosis.

Variables	Values
Regional recurrence	2 (9.5%)
Among positive SLNB	2 (20.0%)
Among negative SLNB	0 (0.0%)
Distant metastasis	3 (14.3%)
Among positive SLNB	3 (27.3%)
Among negative SLNB	0 (0.0%)

Abbreviation: SLNB, sentinel lymph node biopsy.

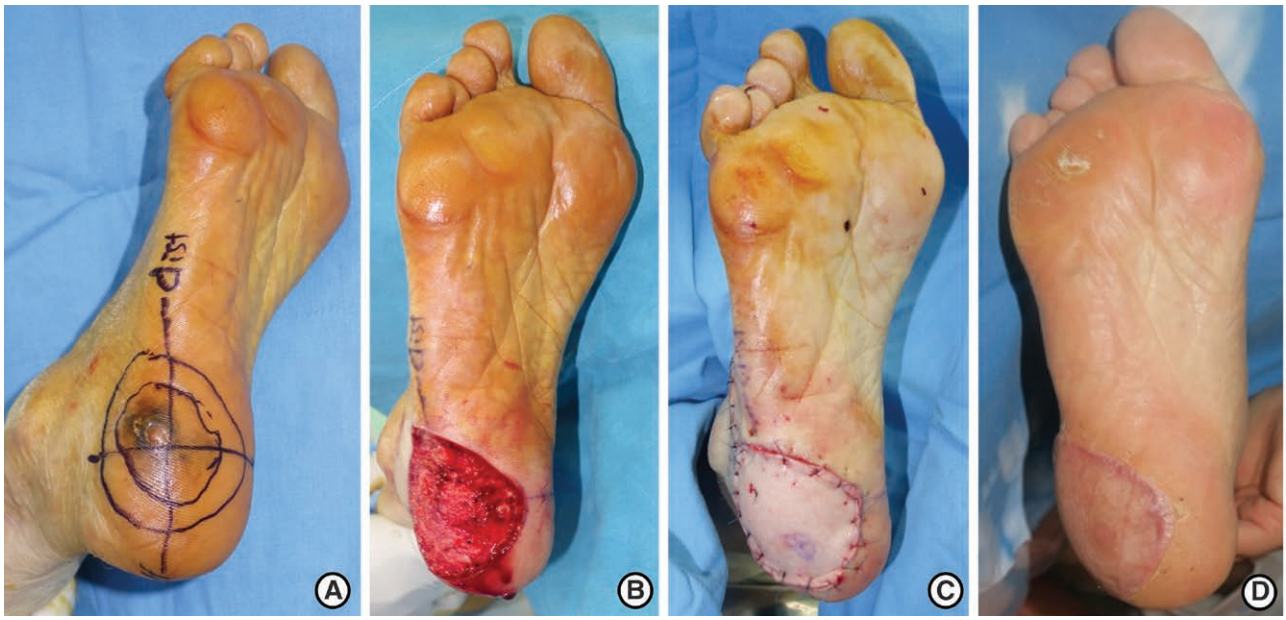

Figure 3. Clinical pictures. A. Preoperative; B. Intraoperative defect; C. Postoperative, immediate; D. Postoperative, 3-month.

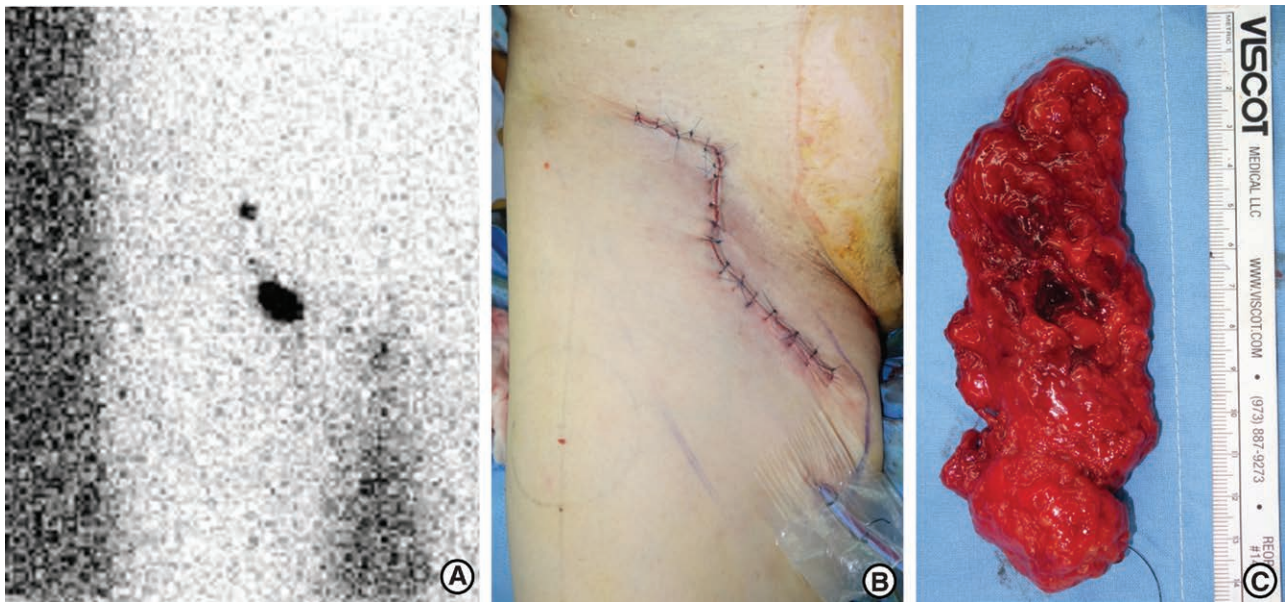

Figure 4. Lymph node dissection. A. Lymphoscintigraphy of the right inguinal area; B. Postoperative picture; C. Dissected inguinal lymph node.

8. Discussion

We found that operation time did not differ between cases with and without inguinal dissection. This was achieved by using a 2-team approach: team A dissected the inguinal lymph nodes, while team B anastomosed vessels and closed the recipient site. However, operation time differed according to the site of SLN due to the time taken to change the position of the patient. With the patient in the prone position for excising popliteal SLNs, the advantage of 2-team approach was decreased. The reconstructive team was unable to harvest the ALT flap at the beginning of the surgery because the operation field first had to be secured. Most postoperative treatments, including radiotherapy, chemotherapy, and immunotherapy were performed in cases of inguinal dissection.

Malignant melanoma of the foot accounts for 3%–15% of all melanomas,[5–7] but plantar malignant melanoma tends to have deeper Clark level and thicker Bleslow depth at the time of diagnosis.[36] Plantar malignant melanoma has higher incidence of recurrence (16%–37%) than other cutaneous malignant melanomas due to its aggressive nature.[5,6,8,9]

It is challenging to surgically resect melanomas of the distal lower extremity, especially the foot or ankle, because it requires wide excisions that can yield large defects.[31] If reliable reconstruction with preservation of foot function cannot be guaranteed following ablative surgery, oncologic surgeons tend to conduct conservative surgeries and use smaller excision margins, which can affect oncologic outcomes, especially local failure rate.[37] In other words, surgical resection with appropriate margins results in low local recurrence rates[9] and the best chances of long-term survival and progression-free survival.[10,11]

The ideal technique for sole reconstruction should meet such requisites as a durable and comfortable weight-bearing surface,

Figure 5. Clinical pictures. A. Preoperative; B. intraoperative defect; C. Postoperative, immediate; D. Postoperative, 2-year.

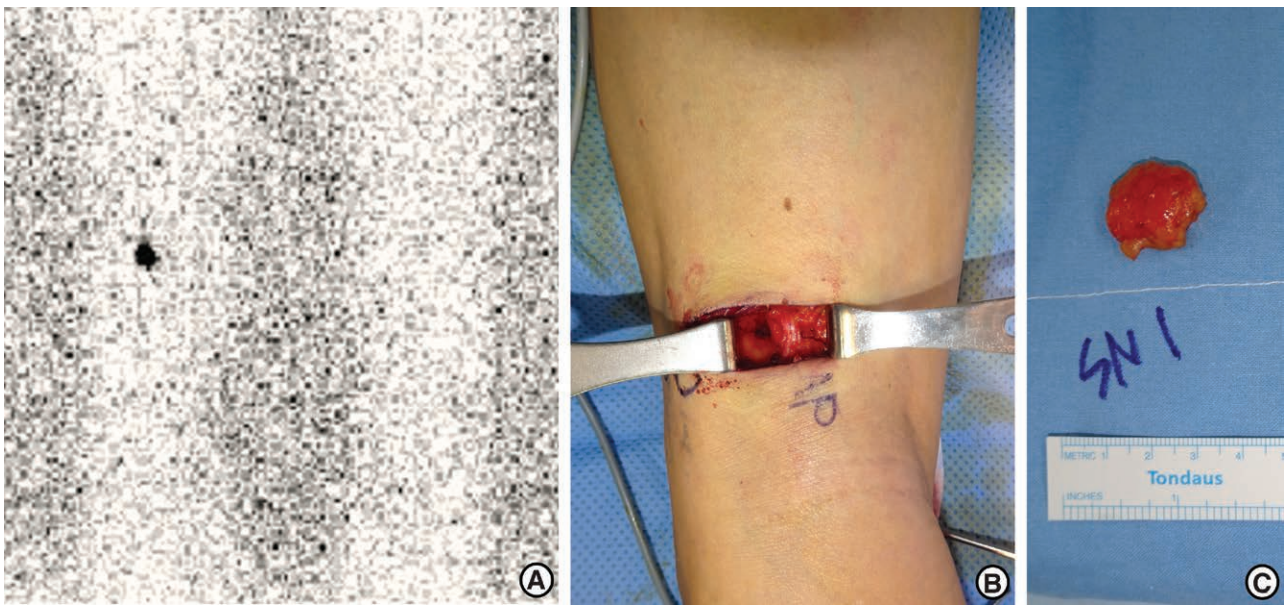

Figure 6. Lymph node dissection. A. Lymphoscintigraphy of right popliteal area; B. Intraoperative picture; C. Dissected popliteal sentinel lymph node.

solid anchoring to deep tissue for resistance to shear force, and adequate protective sensation.[38] Skin grafts tend to conspicuously fail in this region, as they remain vulnerable to trauma and pressure. Reconstructive treatment using similar tissue from the same foot, including medial plantar flap[16–18] and reverse sural flap[19–21] approaches, are good options but are limited by the lack of adjacent soft tissues, flap size, and arc of rotation and subsequent donor morbidity in the plantar region. Therefore, it is often necessary to perform skin grafts or flap coverage.[22,23]

The optimal reconstruction choice for salvage of the foot and ankle often requires the use of distant or free flaps.[31] It has been demonstrated that various foot defects, including diabetic ulcers or posttraumatic wounds, can be successfully reconstructed with free perforator flaps,[23,39–41] and that fasciocutaneous free flaps provides ample volume supply and satisfactory outcomes both functionally and aesthetically.[23] However, reconstruction of oncologic foot defects using fasciocutaneous perforator flaps remains uncommon and the outcomes of such reconstruction remain poorly elucidated[15,33] due to its complex and time-consuming nature, resulting in necessity of good condition of the patient.[42]

Recently, perforator flaps, including medial plantar artery perforator flaps,[43–45] propeller perforator flaps,[46] ALT flaps,[38,47] medial sural artery perforator flaps,[48] and chimeric fashioned thoracodorsal artery perforator flaps,[49] have been described for reconstruction of the sole region. In particular, ALT fasciocutaneous perforator flaps could serve as large, pliable skin flaps and provide sufficient bulk with acceptable donor-site morbidity. Although the ALT flap might be thick in the patients with high body mass index, the thickness of fat tissue decreased to provide a proper contour, even without debulking surgery. Moreover, protective sensation of ALT flap could be recovered by 12 months regardless of sensory nerve anastomosis in the 87.5% of sole reconstruction cases.[38]

The skin of both the heel and the sole of the foot has particular histologic characteristics, presenting a thick epidermis

and dermis with very thin subcutaneous tissue and very sound adherences between the dermis and the muscle below. Thick, dense septa can be found extending from deep fascia to skin.[32,50,51] Whereas, ALT flaps have thinner epidermis and thicker subcutaneous tissue than the heel when examined histologically.[52]

However, histopathological characteristics of the transferred flap change to adapt in various surroundings.[53–56] In the plantar region, flap durability is obtained from incessant stimuli including pressure by weight bearing and shearing by walking, which results in the proliferated epidermis, the hardened dermis, and dense subcutaneous tissue by the collagen infiltration.[23]

A limitation of this paper is that it is not a controlled study. Of course, the operating time is reduced compared to the 1-team approach, but compared to the published literatures,[15,31] the results of the present study are not significantly different in the areas of revision surgery, wound problem, regional recurrence, and distant metastasis. In addition, no recurrence is observed at surgical site such as donor sites, sentinel lymph nodes, and lymph node dissection sites other than the primary lesion, which is the major concern in 2-team approach surgery.

9. Conclusions

The application of a surgical protocol involving a 2-team approach to reconstructing heel defects after wide excision of malignant melanoma using free flap coverage allows division of operative duties and facilitates shorter operation time. Operation time is not significantly longer in cases with inguinal dissection than in cases without inguinal dissection.

Author contributions

Jun Hyeok Kim - Conceptualization, supervision, visualization, writing - oringal draft
Chae Rim Lee - Data curation, formal analysis
Hyo Jeong Kwon - Investigation, Methodology
Deuk-Young Oh - Resources, Supervision
Yong-Joon Jun - Software Supervision
Jong Won Rhie - Validation, Visualization.

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