

· 临床研究 ·

## 运用“断口相合识别技术”修复足踝部严重创伤

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**摘要:** [目的] 介绍“断口相合识别技术”修复严重足踝部损伤治疗技术及其临床效果。[方法] 2015年3月—2020年8月对本院27例足踝部严重创伤者, 运用“断口相合识别技术”有效识别组织原位对合, 彻底清创, 采用多元化组织一体化重建并结合血管寻找新方法和创新促进组织成活技术进行修复。[结果] 所有病患术程顺利, 无肢体坏死等严重并发症。早期皮瓣肿胀4例, 7d以后基本消退; 1例延期愈合外, 经换药以后逐渐愈合; 所有皮瓣受区与供区均最终愈合良好。平均随访(23.8±7.5)个月, 随出院前、术后3个月和末次随访的时间推移, VAS评分显著降低[(4.0±1.3), (2.3±1.1), (1.6±0.8),  $P<0.001$ ], AOFAS评分[(54.3±3.2), (71.0±3.0), (83.9±3.3),  $P<0.001$ ], 踝背伸-跖屈活动度(range of motion, ROM)[(42.7±2.9)°, (52.6±2.6)°, (64.2±3.2)°,  $P<0.001$ ], 足内-外翻ROM[(34.7±3.6)°, (40.7±3.6)°, (53.6±3.9)°,  $P<0.001$ ], 伤肢远端Hight[S0/S1/S2/S3/>S3, (2/9/11/3/2), (1/6/9/7/4), (0/2/3/6/16),  $P<0.001$ ], 静态两点辨别(static 2-point discrimination, 2PD)[(38.0±4.7) mm, (32.3±2.2) mm, (19.0±0.6) mm,  $P<0.001$ ], 动态两点辨别(moving 2-point discrimination, m2PD)[(10.1±0.6) mm, (8.4±0.9) mm, (5.5±0.3) mm,  $P<0.001$ ]均显著改善。[结论] 利用“断口相合识别技术”结合显微外科技术修复严重足踝部毁损伤, 可以最大限度的挽救肢体的功能, 减少伤残率。

**关键词:** 足踝部严重创伤, 断口相合识别技术, 显微外科, 修复重建

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**Repair of severe foot and ankle wound by fracture matching recognition technique** // XU Ning, PAN Feng-yu. Department of Joint Surgery, The 970<sup>th</sup> Hospital, PLA Joint Logistic Support Force, Yantai 264002, Shandong, China

**Abstract:** [Objective] To introduce the technique and clinical consequence of fracture matching recognition technique in repairing severe foot and ankle wound. [Methods] From March 2015 to August 2020, 27 patients with severe foot and ankle wound were treated with the "fracture-matching recognition technique" to effectively identify the tissue in situ. On basis of thorough debridement, the multi-tissue integration reconstruction procedures combined with new method searching vascular vessels and innovative tissue survival promoting ways were adopted for repair. [Results] All the patients had surgical procedures performed smoothly without serious complications such as limb necrosis. Except early flap swelling occurred in 4 cases, which basically subsided 7 days later, and delayed wound healing happened in another patient, who got healed gradually after dressing change, all patients had the recipient and donor areas of the skin flap healed well. The follow-up period lasted for (23.8±7.5) months in a mean. With time elapsed before discharge, 3 months after surgery and at the last follow-up, the VAS score [(4.0±1.3), (2.30±1.1), (1.6±0.8),  $P<0.001$ ], AOFAS score [(54.3±3.2), (71.0±3.0), (83.9±3.3),  $P<0.001$ ], dorsal-plantar flexion range of motion (ROM) [(42.7±2.9)°, (52.6±2.6)°, (64.2±3.2)°,  $P<0.001$ ], inversion-eversion ROM [(34.7±3.6)°, (40.7±3.6)°, (53.6±3.9)°,  $P<0.001$ ], Hight grade distal to the wound [S0/S1/S2/S3/>S3, (2/9/11/3/2), (1/6/9/7/4), (0/2/3/6/16),  $P<0.001$ ], static 2-point discrimination (2PD) [(38.0±4.7) mm, (32.3±2.2) mm, (19.0±0.6) mm,  $P<0.001$ ], and moving 2-point discrimination (m2PD) [(10.1±0.6) mm, (8.4±0.9) mm, (5.5±0.3) mm,  $P<0.001$ ] were significantly improved. [Conclusion] The applying "fracture matching recognition technique" combined with microsurgical technique to repair severe foot and ankle wound does save the limb function to the maximum extent and reduce the disability rate.

**Key words:** severe foot and ankle wound, fracture matching recognition technique, microsurgery, repair and reconstruction

足踝部作为人体行走及负重的核心结构, 其功能性至关重要。足踝部严重创伤(如骨折与脱位、皮肤撕脱与缺损、继发感染等), 若处理不慎可能导致严

重残疾<sup>[1, 4]</sup>。针对此类挑战, 本研究团队创新应用“断口相合识别技术”微观层面实现受损组织的精确对接, 为显微外科修复提供了关键支持。在此基础

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上,结合显微外科技术,实现了对血管、神经及软组织的精细修复。本院2015年3月—2020年8月采用此综合治疗方案已成功修复27例重症足踝部损伤患者,治疗效果满意。现报道如下。

## 1 临床资料

### 1.1 一般资料

2015年3月—2020年8月采用“断口相合识别技术”共修复27例足踝部严重创伤患者。男性24例,女性3例,均为单侧发病。年龄21~57岁,平均 $(39.3 \pm 12.3)$ 岁。致伤情况:机器伤3例,交通伤13例,砸伤11例。局部伤情:27例均为复杂开放损伤,包含内外踝部损伤并骨外露3例,足背皮肤缺损伴感染12例及全足部皮肤逆行撕脱伤4例。皮肤缺损面积为 $12\text{ cm} \times 10\text{ cm} \sim 5\text{ cm} \times 4\text{ cm}$ 。所有患者均无糖尿病、静脉功能不全或外周动脉疾病等明显手术禁忌证且耐受手术<sup>[5,6]</sup>。本研究已通过医院伦理委员会批准[2015(伦)1025],所有病患均签署手术知情同意书。

### 1.2 手术方法

27例复杂开放性损伤均采用“断口相合识别技术”。首先对足踝部毁损伤创面进行彻底清创,充分保留具备生物活性的组织。(1)辨别几何特征:依据骨折碎片,撕裂伤口边缘的凹凸形状、曲率、长度、角度,以及肌腱、血管、神经位置深浅、层次,来进行相应的对合复原,缝合修复;(2)构建局部匹配与拼合:通过皮肤伤口边缘互补性(如凸起与凹陷)筛选对合相邻损伤组织碎片;根据组织层次断口、肌腱断口撕脱的长短及神经马尾状是否撕脱与缩回,找到相应的断端予以缝合修复;(3)实现整体拼合修复:遵循“骨性架构优先复位、软组织张力序贯平衡”原则,先依据骨折几何特征进行复位并用克氏针、钢板或螺钉临时固定,通过骨块之间的“断口互锁效应”实现骨性结构复原,为神经、血管提供精准走行空间,然后采用“节段式血管修复”技术修复动、静脉解除血运障碍,对肌腱、血管、神经的缝合模拟“树枝韧皮-髓芯复合愈合”进行修复;对毁损皮肤缺损采用皮瓣修复及区域性打包加压”技术提高存活率。

对于3例内外踝部损伤骨外露及12例足背皮肤缺损并感染患者根据不同的部位、功能和需求在彻底清创基础上采用股外侧皮瓣修复(9例)及腓肠神经

营养皮瓣修复(6例);4例全足部皮肤逆行撕脱伤则采用吻合血管法予以修复。本组中切取的皮瓣宽度为: $14\text{ cm} \times 12\text{ cm} \sim 7\text{ cm} \times 6\text{ cm}$ ,供区伤口直接缝合或游离植皮覆盖供区创面。术后“三抗”治疗,抬高患肢,密切监测皮瓣血运和肿胀,定期换药观察创面愈合及血运情况,指导患者进行下肢康复功能锻炼。

### 1.3 评价指标

随访观察并记录记录围手术期资料:如手术时间、术中失血量、并发症情况及皮瓣受区与供区创面愈合情况,采用疼痛视觉模糊评分(visual analogue scale, VAS)<sup>[7]</sup>、美国足踝关节协会踝和后足功能评分(American Orthopedic Foot and Ankle Society, AOFAS)<sup>[8]</sup>、踝关节背伸-跖屈活动度(range of motion, ROM)、足内-外翻ROM、改良Highet感觉评级<sup>[8]</sup>、静态两点辨别(static two-point discrimination, s2PD)及动态两点辨别(moving two-point discrimination, m2PD)评价临床效果。

### 1.4 统计学方法

采用SPSS 25.0软件进行统计分析。计量资料以 $\bar{x} \pm s$ 表示,资料正态分布时采用单因素方差分析,资料不符合正态分布,采用秩和检验;等级资料两组比较采用秩和检验。 $P < 0.05$ 为差异有统计学意义。

## 2 结果

### 2.1 临床结果

27例患者均顺利手术,手术时间103~154 min,平均 $(124.6 \pm 13.1)$  min;术中出血量159~318 mL,平均 $(223.7 \pm 30.9)$  mL。早期并发症方面,无血管危象、下肢静脉血栓等严重并发症发生;皮瓣肿胀4例,7 d以后基本消退;1例延期愈合,经换药以后逐渐愈合;所有皮瓣顺利存活,受区与供区创面均最终愈合良好。

### 2.2 随访结果

所有患者均获得随访,随访时间11~36个月,平均 $(23.8 \pm 7.5)$ 个月。随访资料见表1,随着出院前、术后3个月和末次随访时的时间推移,VAS评分、AOFAS评分、踝背伸-跖屈ROM、足内-外翻ROM、以及改良Highet感觉评级、s2PD和m2PD均显著改善( $P < 0.05$ )。末次随访时,所有患者足踝外形接近常态,皮瓣无压力性溃疡,足跟修复区感知觉有所恢复,步态复原。典型病例见图1,2。

表 1. 27 例患者随访资料  
Table 1. Follow-up data of the 27 patients

| 指标                                          | 出院时            | 术后 3 个月        | 末次随访           | P 值    |
|---------------------------------------------|----------------|----------------|----------------|--------|
| VAS (分, $\bar{x} \pm s$ )                   | 4.0 $\pm$ 1.3  | 2.3 $\pm$ 1.1  | 1.6 $\pm$ 0.8  | <0.001 |
| AOFAS (分, $\bar{x} \pm s$ )                 | 54.3 $\pm$ 3.2 | 71.0 $\pm$ 3.0 | 83.9 $\pm$ 3.3 | <0.001 |
| 踝背伸-跖屈 ROM ( $^{\circ}$ , $\bar{x} \pm s$ ) | 42.7 $\pm$ 2.9 | 52.6 $\pm$ 2.6 | 64.2 $\pm$ 3.2 | <0.001 |
| 足内-外翻 ROM ( $^{\circ}$ , $\bar{x} \pm s$ )  | 34.7 $\pm$ 3.6 | 40.7 $\pm$ 3.6 | 53.6 $\pm$ 3.9 | <0.001 |
| Highet 评级 (例, S0/S1/S2/S3/>S3)              | 2/9/11/3/2     | 1/6/9/7/4      | 0/2/3/6/16     | <0.001 |
| s2PD (mm, $\bar{x} \pm s$ )                 | 38.0 $\pm$ 4.7 | 32.3 $\pm$ 2.2 | 19.0 $\pm$ 0.6 | <0.001 |
| m2PD (mm, $\bar{x} \pm s$ )                 | 10.1 $\pm$ 0.6 | 8.4 $\pm$ 0.9  | 5.5 $\pm$ 0.3  | <0.001 |

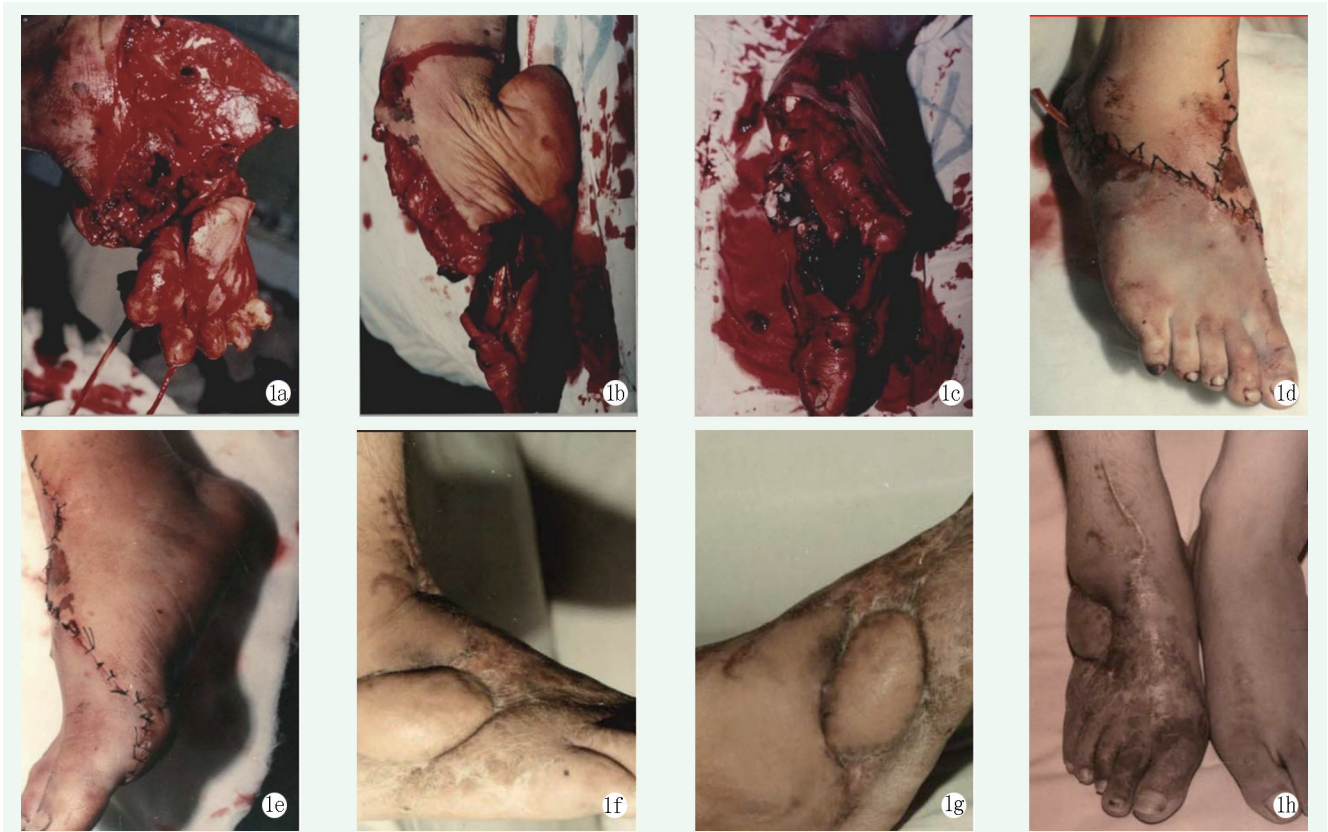


图 1. 患者男性, 28 岁, 因水泥搅拌致左足踝部严重创伤, 应用断口相合识别技术修复。1a: 术前创面正面观; 1b: 术前创面侧面观; 1c: 术前创面俯视观; 1d: 术后即刻正面观; 1e: 术后即刻侧面观; 1f: 术后 3 个月随访正面观; 1g: 术后 3 个月随访侧面观; 1h: 末次随访正面观。

Figure 1. A 28-year-old male suffered from severe trauma to the left foot and ankle by cement blender, was repaired with the fracture matching recognition technique. 1a: Preoperative frontal view of the foot and ankle; 1b: Preoperative lateral view of the foot and ankle; 1c: Preoperative overhead view; 1d: Frontal view immediately postoperatively; 1e: Lateral view immediately postoperatively; 1f: Frontal view 3 months postoperatively; 1g: Lateral view 3 months postoperatively; 1h: Frontal view at the latest follow-up.

3 讨 论

足踝部严重毁损性损伤的组织重建是医学领域的一大挑战<sup>[10, 11]</sup>, 为有效解决组织原位对合难题, 降低肢体伤残发生率<sup>[12]</sup>, 本研究团队提出以下创新性策略与细致规划: (1) 创新采用“断口相合识别技术”: 足踝部结构复杂, 修复需高度精确性, 传统修复方法往往依赖术者的经验和视觉判断, 存在一定局限性,

尤其在处理复杂创伤时, 可能导致组织对合不佳, 影响愈合效果。本文提出的技术通过断面组织质地、损伤边缘及断口走向等关键点进行匹配, 精准实现组织原位对接, 确保创面组织连贯性, 缩短手术时间, 显著提高修复效果; (2) 程序化“一卷、二泡、三重建”清创流程: 以彻底清除坏死组织与污染物为前提<sup>[4]</sup>, 采用“卷地毯”式清创法, 并巧妙运用碘伏、生理盐水溶液泡洗及双氧水冲洗, 确保清创无死角, 同时最大程度保留生命力强的组织。特别强调双氧水



使用时机，以避免清创前使用可能导致的污染扩散；(3) 多元化组织一体化重建策略：①骨骼：依据骨折块特征与断口情况，选用适当固定方式，恢复骨骼支架结构；②肌腱：精确缝合修复，依据损伤部位与层次进行针对性处理；③神经：依据神经解剖结构与断口情况，进行精细的寻找与缝合；④血管：通过解剖部位、层次、管壁厚薄及断端形状，精确寻找并重建血管；(4) 血管寻找新方法：通过观察喷血情况与挤

压远端组织，快速定位血管断端，简化寻找过程；(5) 创新促进组织成活技术：“节段式血管修复”技术，重建肢体血液循环，恢复静脉回流，增加皮肤组织血流供应。①“区域性打包加压”技术，确保无血管组织通过营养渗透成活；②皮瓣移植技术，用于皮肤软组织缺损的覆盖，促进创面愈合<sup>[10]</sup>。以上策略的综合应用，为足踝部毁损伤患者提供全面、高效、精准的治疗方案，显著提升治疗效果。



图 2. 患者男性，45 岁，因车祸致右足踝创伤性毁损伤，断口相合识别技术和腓肠神经营养皮瓣修复术治疗。2a：受伤后创面正面观；2b：受伤后创面侧面观；2c：二期扩创后外观；2d：切取皮瓣；2e：皮瓣修复术后创面外观；2f：拆线后创面外观；2g：术后 3 个月创面外观；2h：1 年后创面及供区外观，均提示术后恢复良好，足踝形态正常，皮瓣无压力性溃疡，供区皮肤无挛缩。

Figure 2. A 45-year-old male suffered from destroyed right ankle injuries in an automobile accident and treated with fracture matching recognition technique and peroneal nerve trophic flap repair. 2a: Frontal view of the wound after injury; 2b: Lateral view; 2c: Appearance of the wound after two-stage expansive debridement; 2d: Appearance of the flap after cutting; 2e: Appearance after flap repair; 2f: Appearance of the wound after removal of stitches; 2g: Appearance of the wound 3 months postoperatively; 2h: Appearance of the wound and the donor area 1 year after operation, revealed normal ankle in shape, the flap without any pressure ulcers, and no shin contracture in the donor area.

对于足踝部严重毁损性损伤，创面感染、愈合延迟及皮瓣坏死是一大难题<sup>[14, 15]</sup>。本研究除 1 例延期愈合外，其余病例均愈合良好，无皮瓣坏死现象。原因分析如下：(1) 程序化无死角清创，既有效预防感染，又保留了生命力旺盛组织；(2) “断口相合识别技术”大幅缩短手术时间，最大限度保留软组织；(3) 所植皮瓣血供丰富，具备较强抗感染能力；(4) 通过静脉移植或多段吻合修复技术，改

善局部血液循环，增强抗菌能力，促进愈合。

针对全足部皮肤逆行撕脱伤，本研究 4 例患者均未出现皮肤缺血性坏死。原因分析如下：(1) 重视静脉血管修复，促进静脉血回流，降低皮肤内组织压力，保证撕脱皮肤的血液供应；(2) 适当抬高患肢促进静脉回流；(3) 打包或加压包扎，使无法通过修复血管改善血供的皮肤通过营养渗透成活；(4) 保持引流通畅，预防皮下积血，为皮肤存

活创造有利条件。

综上所述,结合“断口相合识别技术”与显微外科技术,修复严重足踝部损伤,显著提升肢体功能挽救率,有效降低病残率。然而,本研究尚存不足之处:(1)足踝部严重创伤的恢复效果依赖于创伤类型、手术技术、护理等多方面因素,本文着重于对“断口相合识别技术”在复杂足踝部创面的应用进行研究;(2)样本量有限,未来需积累更多病例,以对“断口相合识别技术”行更深入的临床观察和推广应用。

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## 参考文献

- [1] Yuan K, Zhang F, Lineaweaver WC, et al. The coverage of soft-tissue defects around the foot and ankle using free or local flaps: A comparative cohort study [J]. *Ann Plast Surg*, 2021, 86 (6) : 668–673. DOI: 10.1097/SAP.0000000000002811.
- [2] Turan K, Tahta M, Bulut T, et al. Soft tissue reconstruction of foot and ankle defects with reverse sural fasciocutaneous flaps [J]. *Rev Bras Ortop*, 2017, 53 (3) : 319–322. DOI: 10.1016/j.rboe.2017.05.002.
- [3] Li RG, Zeng CJ, Yuan S, et al. Reconstruction of large area of deep wound in the foot and ankle with chimeric anterolateral thigh perforator flap [J]. *Orthop Surg*, 2021, 13 (5) : 1609–1617. DOI: 10.1111/os.13046.
- [4] 田万成, 张发惠, 潘风雨, 等. 足踝部损伤的显微外科修复与重建 [J]. *中华显微外科杂志*, 2006, 29 (1) : 66–67. DOI: 10.3760/cma.j.issn.1001–2036.2006.01.026.  
Tian WC, Zhang FH, Pan FY, et al. Microsurgical repair and reconstruction of foot and ankle injuries [J]. *Chinese Journal of Microsurgery*, 2006, 29 (1) : 66–67. DOI: 10.3760/cma.j.issn.1001–2036.2006.01.026.
- [5] Korompilias A, Gkias I, Korompilias M, et al. Reverse sural artery flap: A reliable alternative for foot and ankle soft tissue reconstruction [J]. *Eur J Orthop Surg Traumatol*, 2019, 29 (2) : 367–372. DOI: 10.1007/s00590–018–2330–8.
- [6] 李伍建, 何少波, 任聪, 等. 三种皮瓣修复开放性踝关节骨折脱位软组织缺损 [J]. *中国矫形外科杂志*, 2024, 32 (8) : 702–708. DOI: 10.3977/j.issn.1005–8478.2024.08.06.  
Li WJ, He SB, Ren C, et al. Three kinds of flaps for repairing soft tissue defect complicated with open ankle fracture dislocation [J]. *Orthopedic Journal of China*, 2024, 32 (8) : 702–708. DOI: 10.3977/j.issn.1005–8478.2024.08.06.
- [7] Emmerson T, de la Puerta B, Polton G. Genicular artery axial pattern flap for reconstruction of skin defects in 22 dogs [J]. *J Small Anim Pract*, 2019, 60 (9) : 529–533. DOI: 10.1111/jsap.13045.
- [8] Baumhauer JF, Nawoczenski DA, DiGiovanni BF, et al. Reliability and validity of the American Orthopaedic Foot and Ankle Society Clinical Rating Scale: A pilot study for the hallux and lesser toes [J]. *Foot Ankle Int*, 2006, 27 (12) : 1014–1019. DOI: 10.1177/107110070602701202.
- [9] 付炳金, 朱晓东, 杜瑞, 等. 拱顶石穿支皮瓣修复小型创面 [J]. *中国矫形外科杂志*, 2024, 32 (8) : 759–763. DOI: 10.3977/j.issn.1005–8478.2024.08.16.  
Fu RJ, Zhu XD, Du R, et al. Repair of small wounds with keystone design perforator island flap [J]. *Orthopedic Journal of China*, 2024, 32 (8) : 759–763. DOI: 10.3977/j.issn.1005–8478.2024.08.16.
- [10] 林曼滢, 郑海升, 张翔, 等. 单穿支螺旋桨皮瓣修复小腿及足踝部软组织缺损 22 例 [J]. *中华显微外科杂志*, 2023, 46 (6) : 684–688. DOI: 10.3760/cma.j.cn441206–20230626–00111.  
Lin MY, Deng HS, Zhang X, et al. Repair of soft tissue defects of the calf and ankle with a single penetrating propeller flap in 22 cases [J]. *Chinese Journal of Microsurgery*, 2023, 46 (6) : 684–688. DOI: 10.3760/cma.j.cn441206–20230626–00111.
- [11] 杨亮, 周荣, 巨积辉, 等. 游离双侧股前外侧内增压型串联皮瓣修复足踝部大面积创面的临床疗效 [J]. *中华烧伤与创面修复杂志*, 2025, 41 (1) : 61–69. DOI: 10.3760/cma.j.cn501225–20240508–00164.  
Yang L, Zhou R, Ju JH, et al. Clinical effects of free bilateral turbo-charged anterolateral thigh flaps intandem in repairing extensive wounds in the foot and ankle [J]. *Chinese Journal of Burns and Wounds*, 2025, 41 (1) : 61–69. DOI: 10.3760/cma.j.cn501225–20240508–00164.
- [12] Loreti A, Abate O, Arelli F, et al. Reconstruction of hypopharyngeal defects with anterolateral thigh free flap: A single-center retrospective analysis [J]. *Am J Otolaryngol*, 2022, 43 (5) : 103542. DOI: 10.1016/j.amjoto.2022.103542.
- [13] 王成琪. 皮瓣和肌皮瓣修复创伤性组织缺损的作用 [J]. *中华显微外科杂志*, 1999, 22 (1) : 11. DOI: 10.3760/cma.j.issn.1001–2036.  
Wang QC. The role of skin and musculocutaneous flaps in the repair of traumatic tissue defects [J]. *Chinese Journal of Microsurgery*, 1999, 22 (1) : 11. DOI: 10.3760/cma.j.issn.1001–2036.
- [14] Li RG, Zeng CJ, Yuan S, et al. Reconstruction of large area of deep wound in the foot and ankle with chimeric anterolateral thigh perforator flap [J]. *Orthop Surg*, 2021, 13 (5) : 1609–1617. DOI: 10.1111/os.13046.
- [15] 叶琪毅, 林浩, 张文广, 等. 削薄股前外侧穿支皮瓣修复足踝部较大面积软组织缺损 [J]. *中华显微外科杂志*, 2020, 43 (6) : 544. DOI: 10.3760/cma.j.cn441206–20200728–00301.  
Ye QY, Lin H, Zhang WG, et al. Thinned anterolateral thigh perforator flap in repair of large soft tissue defects of foot and ankle [J]. *Chinese Journal of Microsurgery*, 2020, 43 (6) : 544. DOI: 10.3760/cma.j.cn441206–20200728–00301.

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