

· 技术创新 ·

## 游离皮瓣 Taylor 支架治疗踝周骨与软组织缺损<sup>△</sup>

罗桦杰<sup>1</sup>, 王朝辉<sup>1\*</sup>, 余卓安<sup>2</sup>, 詹晓欢<sup>1</sup>, 李卓伟<sup>1</sup>, 杨松<sup>1</sup>

(1. 佛山市中医院修复重建外科, 广东佛山 528000; 2. 广州中医药大学, 广东广州 510006)

**摘要:** [目的] 介绍游离皮瓣联合 Taylor 支架 (taylor spatial frame, TSF) 治疗踝周骨与软组织缺损的手术技术和初步临床结果。[方法] 2016 年 1 月—2020 年 2 月共治疗踝周骨与软组织缺损 16 例患者, 一期行彻底清创, 清除感染坏死骨与软组织, 使用外固定支架临时固定, 缺损创面使用负压海绵覆盖。二期根据创面部位、面积和软组织缺损情况及血管条件分别选用游离背阔肌皮瓣、股前外侧肌皮瓣、腓肠肌内侧肌皮瓣对踝周皮肤缺损进行修复。皮瓣成活后三期根据骨缺损范围预设 TSF 骨延长及胫距融合构型, 术中根据治疗要求, 安装固定 TSF 并完成截骨。术后 1 周根据术前测量的畸形、安装、框架参数制定电子处方, 以 1 mm/d, 分 4 次调整的速度, 开始骨延长及调整 TSF, 最终完成牵张成骨和胫距融合。[结果] 16 例患者均获随访, 随访时间 14~52 个月。术后外固定架总佩戴时间平均 (17.3±2.4) 个月, 愈合时间平均 (14.8±1.4) 个月, 总治疗时间平均 (17.9±2.2) 个月。末次随访时, 胫骨总延长平均 (7.5±1.1) cm。按 AOFAS 踝及后足评分进行评定: 优 12 例, 良 4 例。[结论] 游离皮瓣结合 TSF 治疗踝周骨与软组织缺损, 可有效修复缺损组织, 胫距关节融合成功率高, 负重力线恢复好, 成功重建下肢功能。

**关键词:** Taylor 空间支架, 骨搬运, 游离皮瓣, 踝关节, 胫距融合术

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**Free flap and bone transportation with Taylor spatial frame for bone and soft tissue defects around ankle** // LUO Hua-jie<sup>1</sup>, WANG Chao-hui<sup>1</sup>, YU Zhuo-an<sup>2</sup>, ZHAN Xiao-huan<sup>1</sup>, LI Zhuo-wei<sup>1</sup>, YANG Song<sup>1</sup>. 1. Department of Repair and Reconstructive Surgery, Foshan Hospital of Traditional Chinese Medicine, Foshan 528000, China; 2. Guangzhou University of Traditional Chinese Medicine, Guangzhou 510006, China

**Abstract:** [Objective] To introduce the surgical technique and preliminary clinical results of free flap and bone transportation with Taylor spatial frame (TSF) for bone and soft tissue defects around the ankle. [Methods] A total of 16 patients were surgically treated for bone and soft tissue defects around the ankle from January 2016 to February 2020. In the first stage, complete debridement was performed to remove infected and necrotic bone and soft tissue, temporary fixation was performed with a simple external fixation frame, and the defect wound was covered with vacuum sealing drainage (VSD). In the second stage, according to the wound site, area, soft tissue defect and vascular condition, the free lat dorsal myocutaneous flap, anterolateral femoral myocutaneous flap and medial gastrocnemius myocutaneous flap were used to repair the soft tissue defect. After the survival of the flap, the bone transportation or tibiotalar fusion with TSF were performed at the third stage according to the extent of bone defects. During the last operation, TSF was installed and fixed according to the requirements of treatment with osteotomy. One week after the surgery, an electronic prescription was made according to the deformity, installation and frame parameters measured before surgery. The bone transportation with TSF were adjusted at a rate of 1 mm/d per day, divided into four times, and finally distraction osteogenesis and tibial talus fusion were completed. [Results] All the 16 patients were followed up for 14~52 months, with external frame wearing time of (17.3±2.4) months, the bone healing of (14.8±1.4) months, and the total treatment time of (17.9±2.2) months. At the last follow-up, total tibial lengthening was of (7.5±1.1) cm. The clinical outcome was marked as excellent in 12 cases and good in 4 cases based on AOFAS criteria. [Conclusion] Free flap and bone transportation with Taylor spatial frame can effectively repair bone and soft tissue defects around the ankle, with high success rate of tibiotalar fusion, good recovery of alignment and successful reconstruction of lower limb function.

**Key words:** Taylor spatial frame, bone transportation, free flap, ankle, tibiotalar fusion

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作者简介: 罗桦杰, 主治医师, 硕士研究生, 研究方向: 修复重建外科, (电子信箱)jackluo1405@163.com

\* 通信作者: 王朝辉, (电子信箱)wangzh6818@163.com

高能量创伤导致的踝周损伤其特点是踝周严重开放骨折及骨缺损、皮肤软组织大面积缺损<sup>[1]</sup>。踝周软组织浅薄，韧性较差，损伤后修复难度大，感染概率高，后期出现骨缺损、关节不稳、肢体短缩畸形、骨不连、骨髓炎等并发症，最终可导致肢体关节功能丧失，甚至面临截肢<sup>[2]</sup>。以往主要采取早期带血管的肌肉皮瓣覆盖开放伤口<sup>[3]</sup>，再使用 Ilizarov 环型支架或单边支架行骨延长，术后往往出现过早覆盖的皮瓣感染坏死、胫骨旋转和角度畸形、骨性关节炎等并发症。随着新型 Taylor 支架 (taylor spatial frame, TSF) 出现，截骨延长术和胫距关节融合术的结合，取得了较好的疗效，能有效减少保肢后关节疼痛和并发症的发生，患者接受度高<sup>[4-8]</sup>。TSF 能提供更稳定的足踝部支架构型，提高抗压和抗扭转能力，结合计算机出具处方，骨延长和关节对接更精准<sup>[9-11]</sup>。本科室采用中期游离皮瓣移植联合 TSF 骨延长胫距关节融合术治疗 16 例踝周骨与软组织缺损患者，该方式操作简便，关节融合精度高，能有效保肢，报道如下。

## 1 手术技术

### 1.1 术前准备

详细采集患者病史，完善术前检查，排除手术禁忌证。根据创面部位、面积和软组织缺损情况及血管条件选用不同游离皮瓣修复，通过多普勒彩超确定供区皮瓣血管穿支。拍摄 TSF 术前双下肢全长 X 线片、标准踝关节正侧位 X 线片评估肢体长度、力线及骨缺损长度，设定截骨平面。根据骨缺损长度、肢体周径预设泰勒支架环。

### 1.2 麻醉与体位

蛛网膜下腔麻醉联合连续硬膜外麻醉或全身麻醉，患者取仰卧位或侧卧位。

### 1.3 手术操作

一期手术，清创，临时外固定。常规消毒，铺无菌巾，大量生理盐水、双氧水、安尔碘反复冲洗创面，清除坏死软组织及污染物、清理无活性骨质 (图 1a)，骨水泥填塞骨缺损空腔，外固定支架临时固定，予以负压封闭引流 (vacuum sealing drainage, VSD) 材料覆盖软组织缺损创面 (图 1b)。

二期手术，游离皮瓣移植。以术前标记胸背动脉穿支穿出点位置为起点，以该起点至髂后上棘的轴线设计皮瓣 (图 1c)，于皮瓣前缘逐层切开皮肤，显露背阔肌及前锯肌肌间隔，分离并显露胸背动脉，充分游离血管主干至背阔肌血管进肌处，结扎前锯肌支，

沿此血管束向近心端游离解剖至胸背动脉起点处，同时将胸背动脉和胸背神经分离，切开肩背部皮瓣余下设计线，从背阔肌前缘皮瓣下方切断背阔肌的近侧腱部和远端肌肉部，将皮瓣肌皮部分完全分离，检查远端肌肉渗血良好后，根据血管蒂所需长度予以切断并结扎血管，取下皮瓣，分层缝合切口。将皮瓣移植到受区，将胸背动脉、静脉与胫后动脉、伴行静脉行端对端吻合。仔细检查血管吻合质量及皮瓣血运良好之后，分层缝合切口，使用 VSD 材料覆盖部分创面，以减少皮瓣张力 (图 1d)。

三期手术，更换 TSF，骨搬移。透视标记位置，近端固定环：平行于胫骨平台关节面，平台下约 2 cm；中间固定环：取剩余胫骨的中段为中间固定环平面；距骨中段平面：用于距骨体穿 schanz 螺钉辅助固定足环。胫骨截骨平面 (一般为胫骨结节下 5 cm)。支架安装及截骨：于胫骨近端关节面下 2 cm 平行关节面且与水平面成约 60° 置入第 1 枚橄榄针，将近端环与中间环整体固定于橄榄针，透视确认环垂直于胫骨，考虑小腿皮肤条件，尽量将胫骨置于环的中央，近端环固定标记至小腿近端中央，且屈膝最大角度时近端环不影响屈膝功能锻炼，确认其位置满意后近端再分别使用 1/2/3 孔立柱固定连接 3 枚 5.0 schanz 螺钉从前、内、外侧固定近端骨段，再在外侧与水平面成约 60° 置入 1 枚橄榄针加强固定。中间环予以 1 枚橄榄针及 1~2 枚 5.0 schanz 钉固定。远端足环通过跟骨 2 枚交叉橄榄针，前足两枚交叉橄榄针固定，同时需要在距骨体置入 1 枚 5.0 schanz 钉固定。6 根伸缩杆连接足环，使用拉杆器加压固定全部橄榄针。透视确认固定位置满意后，于预设的截骨平面做约 1.5 cm 小切口，锐性分离至骨膜，2.8 mm 钻头扇形钻孔后以骨刀微创皮质截骨，延长 4 根内螺纹杆 3~5 mm，透视下确认截骨成功 (图 1e, 1f)，回调螺纹杆加压截骨端固定，缝合骨膜及术口。再切开胫骨及踝部骨缺损创面，清理骨缺损端瘢痕组织，修整胫骨残端及距骨关节面，彻底止血后放置引流，关闭术口。

### 1.4 术后处理

根据参数制定电子处方，术后 1 周根据电子处方以 1 mm/d，分 4 次调整的速度调整支架，术后定期拍摄 X 线片监测截骨延长矿化情况及矫正情况，及时修正电子处方及更换调整杆。视骨端对合情况，必要时可行会师端清理及植骨。成骨满意时，可拆除第 1、2 层部分固定螺丝行支架动力化。去拐负重行走无痛后即可拆除支架，佩戴护具保护肢体 4 周。



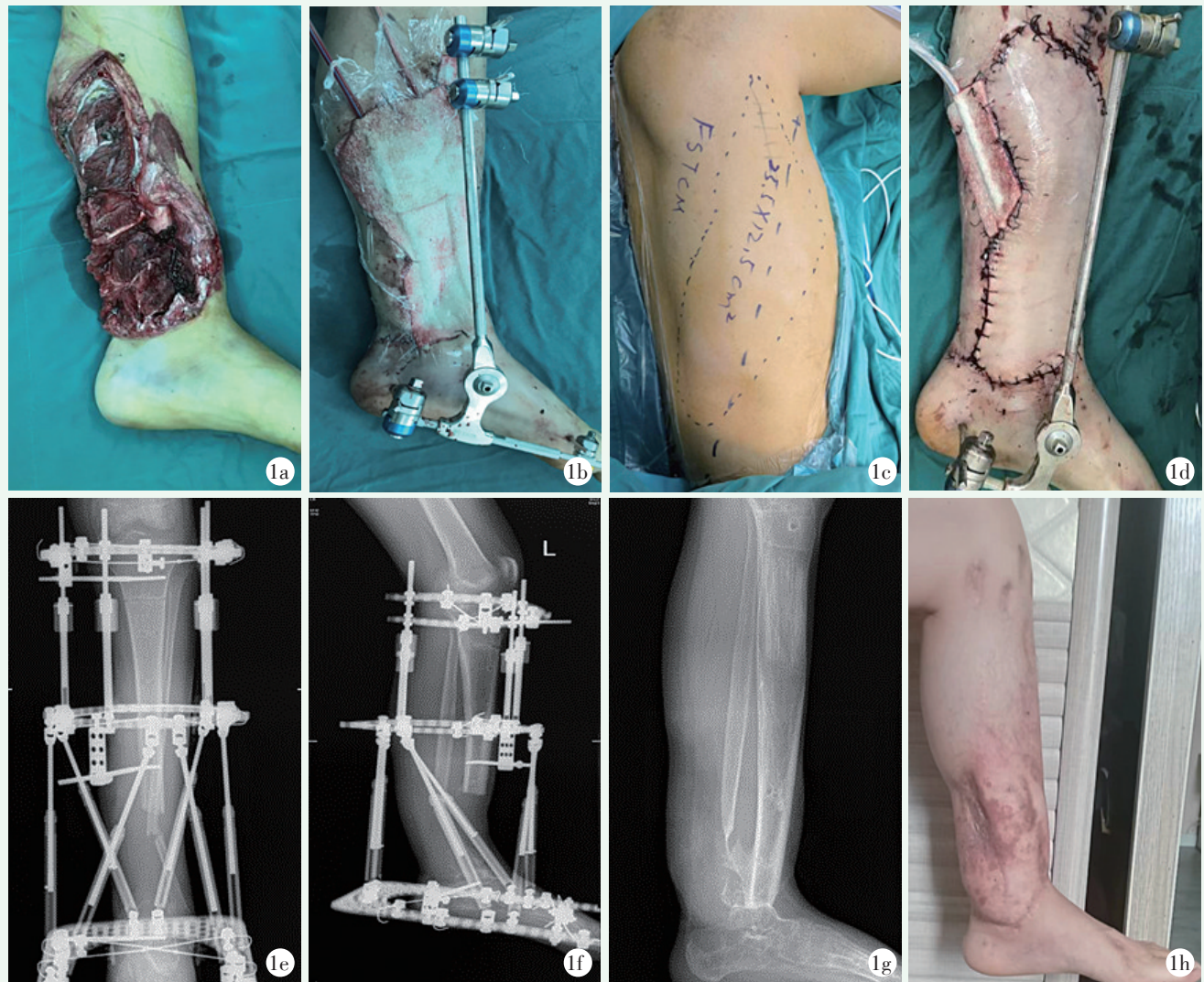


图 1. 患者男性, 23 岁。左小腿爆炸伤; 左小腿下段皮肤软组织缺损; 左小腿开放性踝关节骨折并骨缺损。手术方式: I 期行左小腿清创术、踝关节支架外固定术、负压海绵封闭引流术, II 期行左小腿游离皮瓣修复术, III 期行 Taylor 支架骨延长胫距关节融合术。1a: 清创前创面外观; 1b: 清创术后, 临时外固定架固定; 1c: 游离皮瓣供区术前规划; 1d: 游离皮瓣修复术后外观; 1e, 1f: 更换 TSF 后, X 线片示胫骨缺损约 10.6 cm, 胫距对位满意; 1g: TSF 术后 24 个月后侧位 X 线片示胫距融合成功, 维持于功能位; 1h: TSF 支架拆除后, 足踝接近正常外观。

Figure 1. A 23-year-old male with explosion injury in left lower leg showed skin and soft tissue defects, ankle joint open fracture and bone defect of left lower leg. Patient received complete debridement, ankle joint external fixation, and vacuum sealing drainage in the first stage, free dorsal myocutaneous flap in the second stage, and Taylor spatial frame tibiotalar fusion in the third stage. 1a: Appearance of wound after debridement; 1b: Appearance after temporary fixation with a simple frame; 1c: Preoperative planning of free flap before the second stage; 1d: Appearance after free flap transplantation; 1e, 1f: X-rays after TSF showed tibial defect about 10.6 cm, while proper tibiotalar alignment; 1g: Lateral radiographs 24 months after TSF revealed tibiotalar fusion without angulation; 1h: Nearly normal appearance after TSF removed.

## 2 临床资料

### 2.1 一般资料

2016 年 1 月—2020 年 2 月 16 例踝周骨与软组织缺损患者接受游离皮瓣结合 TSF 治疗, 其中男 13 例, 女 3 例; 年龄 15~48 岁, 平均 (28.5±7.5) 岁; 左侧 6 例, 右侧 10 例。患者均为踝关节创伤性骨与

软组织缺损, 踝关节粉碎性骨折及脱位, 胫骨缺损范围为 3.8~9.9 cm, 平均 (7.4±0.7) cm。皮肤缺损面积范围为 9 cm×15 cm~19 cm×31 cm。本研究已获得本医院伦理委员会批准 (KY [2023] 092), 所有患者均知情同意。

### 2.2 初步结果

采用游离皮瓣修复软组织缺损创面, 分别采用游离背阔肌皮瓣 4 例、游离股前外侧肌皮瓣 8 例、游离

腓肠肌内侧肌皮瓣4例。皮瓣均一期成活，后采用TSF行骨延长胫距融合术，其中有4例需后续植骨，植骨后骨牵张端和骨吻接端骨质均完全愈合，术后发现钉道感染5例，2例更换固定位置得以控制，其余换药治疗后好转。术后外固定架总佩戴时间为5~30个月，平均 $(17.3 \pm 2.4)$ 个月，骨愈合时间平均为 $(14.8 \pm 1.4)$ 个月，总治疗时间平均为 $(17.9 \pm 2.2)$ 个月。术后无支架松动、骨不连发生。

16例患者均获随访，随访时间14~52个月，平均 $(35.1 \pm 7.4)$ 个月。末次随访时，胫骨总延长4~10 cm，平均 $(7.5 \pm 1.1)$  cm。依据效采用美国骨科足踝外科协会(American Orthopaedic Foot and Ankle Society, AOFAS)踝及后足评分<sup>[12]</sup>进行评定：优12例，良4例。典型病例24个月后影像和外观见图1g, 1h。

### 3 讨论

踝周创伤后的骨与软组织缺损是一种严重的开放复合损伤，常导致严重的创面污染，并可能引发骨与软组织感染、骨不连和畸形，严重者需要截肢<sup>[13]</sup>。保肢的关键在于覆盖缺损软组织的创面和修复骨缺损，同时保留踝关节的功能。踝周软组织浅薄，韧性较差，缺损较大者不适合用邻近皮瓣修复创面。游离肌皮瓣具有高耐久性和强大的生存能力，柔韧性较好，血供可靠，还可附带肌肉，常用于修复足踝缺损，重建患肢功能<sup>[14]</sup>。有研究评估了骨延长关节融合术治疗下肢骨缺损患者的疗效，并认为该手术能有效保肢并减少术后关节疼痛和并发症的发生，允许患者恢复高水平的活动和独立功能<sup>[15]</sup>。

传统游离皮瓣的大小设计要求与受区保持等大或适当放大，以适应移植过程中受牵拉导致的皮瓣微小血管损伤及循环障碍。供区或需二期缝合或行植皮术，受区术后由于静脉回流障碍及皮瓣放大会非常臃肿。本方法中期使用游离皮瓣修复创面，设计皮瓣宽度时比受区面积小，使用负压封闭引流技术覆盖部分创面以减少皮瓣张力，待皮瓣消肿后，再行二期缝合。此方法可使供区伤口一期线性缝合，足踝受区皮瓣更接近正常外观，无需再行皮瓣修整术。

在胫距融合术过程中，足踝应维持在足背伸 $0^\circ$ 、外翻 $5^\circ$ 、外旋 $5^\circ \sim 10^\circ$ 的姿态，平面倾斜使得足部相对于髌骨外旋 $15^\circ$ ，且确保距骨正确位于胫骨下方，从而最大限度地提升距骨的表面和稳定性。Kovoor等<sup>[16]</sup>在使用Ilizarov支架进行关节融合术时，

出现了3例马蹄足畸形，9例需要再次手术调整融合平面；Zarutsky等<sup>[17]</sup>的研究中，有16%的患者融合角度较差。Fragomen等<sup>[18]</sup>在踝关节融合术中使用TSF，取得了80%的融合率，且无成角畸形。在本方法中，TSF能够在各个阶段调整任意骨端平面角度，确保关节融合的精确性，并支持患者在胫距关节融合过程中同步进行负重训练<sup>[19, 20]</sup>。

综上所述，游离皮瓣TSF治疗踝周骨与软组织缺损能有效控制深部暴露感染，减少高能量创伤后遗症，重建肢体外观，恢复患者高水平的活动和功能独立性。

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