the removal of antibiotic nails that have been implanted for more than two months. They found that proximal incarceration of the nail requiring debridement of bone could occur and might need to be addressed using osteotomes [1]. Paley and Herzenberg also retained their cement-coated rods for up to 753 days without any major complication except rod fracture in one patient [5].

There is one study by Selhi et al. in which in some cases of unlocked ACRs were used for infected non-unions and these were retained for a longer period of time in order to achieve bone healing despite the absence of rotational stability. ACRs were kept for a period ranging from 6 weeks to 22 months with an average of 10.6 months [8]. These rods were usually retained until bony union occurred or secondary procedures like external fixation, intramedullary nailing, and/or bone grafting was performed.

2. ACRs can also be used as locked ACR with adequate biomechanical stability in infected long bone non-unions for both local delivery of antibiotics and provision of stable biomechanical conditions for consolidation of the non-union site [9–11]. For this indication, several retrospective case series (with a maximum of 110 cases in one study) exist. Good clinical outcomes with a healed uninfected bone in 105/110 patients (95%) was demonstrated [9]. Removal of the ACR was not reported in the articles and one can assume that the implants were left in place in order to not weaken the bone.

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3.6. TREATMENT: WOUND COVERAGE

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QUESTION 1: Is there evidence to support one type of flap coverage over another (e.g., muscle over fasciocutaneous flap) after open tibial fractures?

RECOMMENDATION: Different types of flap coverage after open tibial fractures have essentially equivalent and comparable outcomes in terms of flap survival, bone healing, stress fracture, infection, chronic osteomyelitis and donor site morbidity. Local flaps should be considered in low energy trauma, when available. The type of flap should be tailored based on the extent and the depth of the soft tissue defect and the location of the fracture. In high energy fractures of the tibia, muscle flaps may offer a more reliable reconstruction with fewer flap failures and fewer reoperation rates.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 95%, Disagree: 5%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Multidisciplinary management of severe open tibial fractures with radical debridement, skeletal fixation and early stable coverage is essential for infection prevention and high-quality, cost-efficient trauma care [1]. The Gustilo-Andersen grading system of open tibial fractures is a significant prognostic factor of infectious complications and non-unions [2]. Open fractures of the tibia have a high incidence of infection and malunion [3,4]. Wound coverage does not only prevent wound desiccation and infection, but also contributes to fracture repair by serving as a local source of stem or osteoprogenitor cells, growth factors and vascular supply [5,6].

There is a growing body of evidence demonstrating that the biological characteristics of the tissues in a flap can significantly influence fracture healing, and the rate of delayed union or non-union. Timing of soft tissue coverage is also a critical determinant of the length of in-hospital stay and most of the early postoperative complications and outcomes [7]. Early coverage has been associated with higher union rates and lower complication and infection rates compared to those reconstructed after 5-7 days [2,5,7–9]. Furthermore, early reconstruction improves flap survival, as microsurgical free flap integration becomes more challenging with a delay due to an increased pro-thrombotic environment, tissue edema and the increasingly friable vessels. Only those patients presenting to facilities with an actual dedicated ortho-plastic trauma service are likely to receive definitive treatment of a severe open tibia fracture with tissue loss within the established parameters of good practice [7]. “Fix and flap” is being recommended for specialist hospitals where the expertise is available. Antibiotic bead pouches to decrease infection rates have been advocated when there is segmental tissue loss, gross contamination or established infection as pre-flap tissue infection seems to be an independent predictor of adverse flap and skeletal reconstruction outcomes [10,11].

Fasciocutaneous flaps may be better suited and superior compared to muscle flaps for coverage of the shallow defects at the rapidly uniting metaphyseal fractures around the ankle, particularly with no massive bone or soft tissue loss [6,10,12]. They are easier to monitor postoperatively and tend to have better venous and lymphatic drainage with less acute swelling and better aesthetic appearance [10,13]. Additionally, they become potentially sensate and pedicle-independent from secondary neuro-angiogenesis permitting low-risk flap elevation for subsequent procedures [10,14,15].

Human stromal cells derived from muscle exhibit a significantly greater potential for osteogenesis than those from fasciocutaneous tissue, including both skin and adipose tissue, and are equivalent to those from bone marrow [2,16,17]. Muscle flaps covered with skin grafts in direct apposition with diaphyseal fractures help to obliterate the dead space, reducing potential complications associated with hematoma formation. They may be superior in eliminating bacteria from the wound bed [5] and enhancing healing, but remain pedicle-dependent and difficult to elevate for secondary procedures such as bone grafting. Muscle-only flaps may also have a false high rate of re-operation due to difficult postoperative monitoring. An alternative with the biological benefits of both is a chimeric flap, such as the free anterolateral thigh flap, which includes a segment of *vastus lateralis* [11,14]. Muscle flaps with a cutaneous skin paddle are easier to monitor and thus have a higher salvage rate. Rotational flaps with fasciocutaneous tissue and muscle for proximal defects have shown significantly more complications including infection, necrosis or partial flap loss, compared to free muscle flaps in patients with the most severe grade of osseous injury (44% compared to 23%), and are more likely to require operative re-intervention [6,18].

The selection of proper free flaps for the appropriate defects is also of critical importance, as those with extensive tridimensional tissue loss need free muscle flaps because they conform better to such complex defects [5]. However, free fasciocutaneous flaps are reliable and effective for covering the less three-dimensional distal third and ankle open tibial fractures and can better tolerate the subsequent secondary surgical procedures [11,14,15,19]. It is also important to not underestimate donor-site morbidities [6,13,18]. Surgeon experience and familiarity with the flap should also be an important factor in flap selection. However, the dilemma of choosing between muscle and fasciocutaneous flaps is less relevant than identifying the patient that is at risk of a poor outcome and managing them appropriately [12–14,16]. Finally, there seem to be few significant differences between muscle and fasciocutaneous flaps or between local and free flaps [12,15,19–21]. Although not identified in the Search criteria the following article was felt to be important enough to be included, as it is a recent retrospective study of 39 patients with Gustillo IIIB tibial fractures, muscle flaps may be preferred over fasciocutaneous flaps in these patients. Radiographic assessment of these patients revealed a significantly greater percentage of patients treated with a muscle flap reaching fracture union by six months. There was no statistical difference between muscle and fasciocutaneous flaps at 3 or 12 months though [22]. However, local flaps are preferable in low velocity trauma and free tissue transfer appears to have advantages in high-velocity injuries [10,16].

Published studies on reconstruction of traumatic defects of the tibia are mostly retrospective studies with small, heterogeneous patient cohorts. A few of these compare muscle with fasciocutaneous flaps, but include a wide variety of patients and clinical indications, without sufficient details on the criteria used to select coverage of open tibial fractures [11,12,21]. The outcome measures between studies are different, as not all studies report time to union of the fracture, rates of deep infection or even flap survival. Overall, there is little difference in the clinical outcome with regard to infection rates, wound healing or fracture union, but no study is sufficiently powered to answer these questions. These parameters preclude meaningful systematic review or meta-analysis that can provide standardized guidance for the use of different flap options in the management of open fractures of the tibia [1,11].

To improve the patient's outcome, appropriate international consensus guidelines are required, breaking down also the length of hospital stay and the overall healthcare cost [1].

At this point, based on our understanding of the literature, we believe that different types of flap coverage after open tibial fractures have essentially equivalent and comparable outcomes in terms of flap survival, bone healing, stress fracture, infection, chronic osteomyelitis and donor site morbidity, with the timing of the coverage also being crucial. The type of flap should be based on the extent and the depth of the soft tissue defect, location of the fracture and surgeon experience.

More specifically, if we have to categorize them:

1. In low-energy trauma, local muscle or fasciocutaneous flaps should be considered the reconstruction of choice, if they are available.
2. In high-energy injuries such as open fractures of the tibia, muscle flaps may offer a more reliable reconstruction with fewer flap failures and lower reoperation rates. Free muscle flaps are more advantageous for the reconstruction of tridimensional bone and soft-tissue defects.
3. In patients with simple defects around the distal tibial or ankle, fasciocutaneous flaps may offer a better option.

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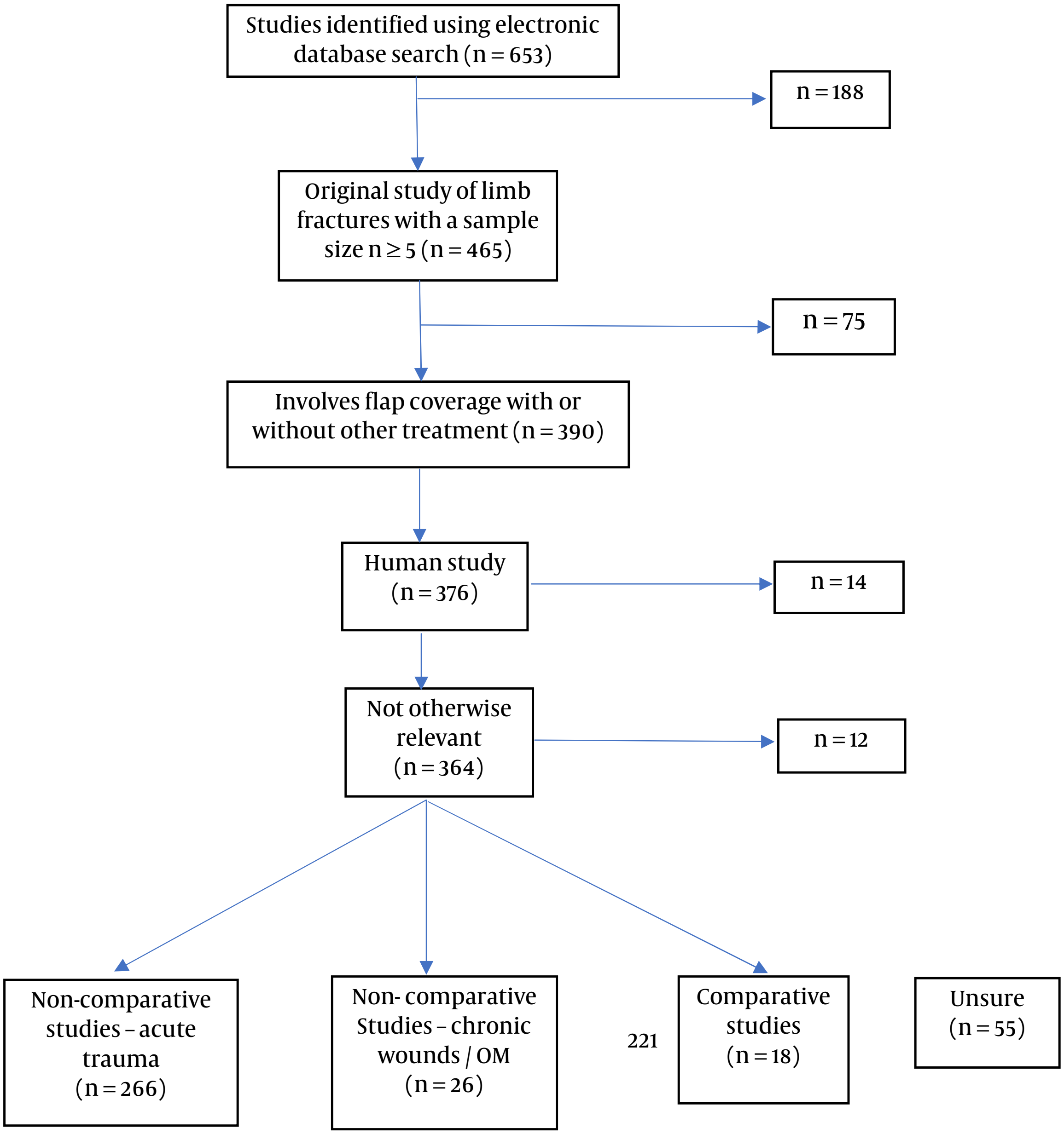

FIGURE 1. Flowchart of literature review.

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