Injury, Int. J. Care Injured 47 (2016) 595–604

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Review

Influence of implant properties and local delivery systems on the outcome in operative fracture care

W-J. Metsemakers [a,b,*], T.F. Moriarty [a], S. Nijs [b], H.C. Pape [c], R.G. Richards [a]

[a] *AO Research Institute Davos, Switzerland*
[b] *University Hospitals Leuven, Department of Trauma Surgery, Leuven, Belgium*
[c] *University of Aachen Medical Center, Department of Orthopaedic Trauma, Aachen, Germany*

ARTICLE INFO

Article history:
Accepted 15 January 2016

Keywords:
Complications
Nonunion
Compromised fracture healing
Implant-related infection
Titanium
Stainless steel
Gentamicin
Coating

ABSTRACT

Fracture fixation devices are implanted into a growing number of patients each year. This may be attributed to an increase in the popularity of operative fracture care and the development of ever more sophisticated implants, which may be used in even the most difficult clinical cases. Furthermore, as the general population ages, fragility fractures become more frequent. With the increase in number of surgical interventions, the absolute number of complications of these surgical treatments will inevitably rise. Implant-related infection and compromised fracture healing remain the most challenging and prevalent complications in operative fracture care. Any strategy that can help to reduce these complications will not only lead to a faster and more complete resumption of activities, but will also help to reduce the socio-economic impact. In this review we describe the influence of implant design and material choice on complication rates in trauma patients. Furthermore, we discuss the importance of local delivery systems, such as implant coatings and bone cement, and how these systems may have an impact on the prevalence, prevention and treatment outcome of these complications.

Contents

---

[*] Corresponding author at: Department of Trauma Surgery, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium.
E-mail address: wilhelmus.metsemakers@uzleuven.be (W.-J. Metsemakers).

http://dx.doi.org/10.1016/j.injury.2016.01.019
0020–1383/

Introduction

The most challenging musculoskeletal complications in trauma surgery are implant-related infection and compromised fracture healing [1–5]. These complications may result in permanent functional loss or even amputation in otherwise healthy patients [6]. Furthermore, the reported socio-economic effect is significant. Darouiche published that in cases of implant-related infection, the costs per patient could be as high as 15,000 USD [3]. Hak et al. stated that the direct treatment cost of an established nonunion was 11,000 USD [5]. In a study by Chung et al., amputation was compared to limb salvage in grade IIIb and IIIc open tibia fractures. The reported lifetime cost, in complicated cases that underwent amputation, could be up to 680,000 USD [7].

Accurately estimating the impact of fracture related complications has been hampered by the lack of clear definitions for these complications: for example, there is a lack of consensus regarding the definition of compromised fracture healing, for which there are no available standard criteria [1]. '*Compromised fracture healing*' and '*nonunion*' are general terms for healing disturbances, and are used interchangeably in this text.

In this review, we describe the latest research aimed at understanding the factors that may lead to implant-related infection, fracture healing complications, and the development of strategies to prevent and treat them. In particular, we describe the contribution of implant properties and local delivery systems on complications in fracture care. Data will be drawn from preclinical experimental research as well as translational and clinical studies to illustrate the current research directions in this field.

Implant choice and design

Plate design and outcome

The influence of the implant on the outcome in fracture care has been described in different publications over the past decades [8–12]. Over time, different plate concepts or designs have been created, from the dynamic compression plate (DCP), the limited contact DCP (LC-DCP) (Fig. 1), through to point contact fixator (PC-Fix) and more recently the locking compression plate (LCP) [8]. These devices have been developed to improve fracture healing, reduce soft tissue and vascular damage but it also has been found that these devices have a different susceptibility to infection [8,13]. Experimental studies demonstrated that implant designs that reduce the area of necrosis in and near the area of contact with the bone have reduced infection rates [14]. This is believed to be due to the fact that infection spreads along a contiguous area of necrosis [14]. The goal of biological internal fixation is to minimise and isolate bone-implant contact, whilst at the same time allow adherence or integration with adjacent tissue to avoid a fluid-filled dead space.

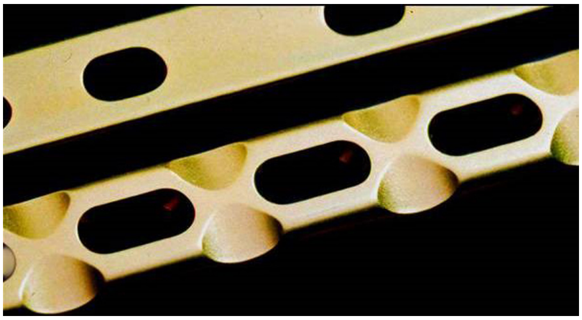

Fig. 1. Dynamic compression plate (DCP; top) and limited contact dynamic compression plate (LC-DCP; bottom). In the LC-DCP design the area of plate-bone contact (footprint) is greatly reduced thus improving cortical perfusion. Images reproduced with kind permission of the Copyright by AO Foundation, Switzerland [12].

The DCP provides fixation by compression of bone fragments across the fracture gap and also compression between the plate and the underlying bone across a large footprint [6]. The large area of compression results in compression induced restriction of blood flow to the periosteum and in the bone, leading to tissue necrosis [8]. The more recently developed, so-called locked internal fixators (*e.g.* PC-Fix and Less Invasive Stabilization System (LISS)), consist of plate and screw systems where the screws are locked in the plate, which reduces the area of contact between the plate and bone minimising, the damage caused to the periosteum (Fig. 2) [8,15].

The greater protection of the periosteum provided by the PC-Fix, leading to greater viability of tissues, improved fracture healing by reducing tissue necrosis, but also improved resistance to infection in comparison with DCP implants by the same mechanism [8]. Eijer et al. investigated, in a rabbit model, local infection rates after fracture fixation with plate osteosynthesis, performed by different implantation techniques [14]. The overall infection rate was higher for the DCP-group with surface contact compared with the PC-Fix group with point contact. The development of the LCP has only been possible based on the experience gained with the PC-Fix [8,12,15]. The LCP with combination holes can be applied, using a conventional technique (compression principle), a bridging technique (internal fixator principle), or a combination technique (compression and bridging principles), depending on the fracture type [12,15].

Nail design, reaming and outcome

IMN was already introduced by Küntscher in 1939 [16]. It is the treatment of choice for shaft fractures of long bones. With respect

Fig. 2. The concept of the Less Invasive Stabilization System (LISS) comprises a contoured plate to which the screws interlock. Stability comes from the angular stability of the plate-screw interface and not from friction between plate and bone. By this method the system minimises implant-to-bone contact and consequently avoid vascular damage to the osseous blood supply.