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David King, Sean McGinty

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Assessing the potential of mathematical modelling in designing drug-releasing orthopaedic implants

David King[1], Sean McGinty[1,*]

Abstract

Orthopaedic implants have been the subject of intense research in recent years, with academics, clinicians and industrialists seeking to broaden our understanding of their function and potential consequences within the human body. Current research is focussed on ways to improve the integration of an orthopaedic device within the body, whether it be to encourage better osseointegration, combat possible infection or stem the foreign body response. A key emerging strategy is the controlled delivery of therapeutics from the device, which may take the form of, for example, antibiotics, analgesics, anti-inflammatories or growth factors. However, the optimal device design that gives rise to the desired controlled release has yet to be defined. There are many examples in the literature of experimental approaches which attempt to tackle this issue. However, the necessity of having to conduct multiple experiments to test different scenarios is a major drawback of this approach. So enter stage left: mathematical modelling. Using a mathematical modelling approach can provide much more than experiments in isolation. For instance, a mathematical model can help identify key drug release mechanisms and uncover the rate limiting processes; allow for the estimation of values of the parameters controlling the system; quantify the effect of the interaction with the biological environment; and aid with the design of optimisation strategies for controlled drug release. In this paper we review current experimental approaches and some relevant mathematical models and suggest the future direction of such approaches in this field.

Keywords: Orthopaedic implants, Controlled release, Mathematical modelling, Drug delivery

1. Introduction and background

1.1. Background

Orthopaedic implants (OIs) have proven to be a very successful addition to the field of medicine. Examples of these devices include plates, screws and intramedullary rods to stabilise fractures, prosthetic hip and knee joints, and replacement intervertebral discs. Traditionally, OIs were designed to serve one of two purposes: either to act as a fixation device to provide mechanical stabilisation or to replace a joint or bone, such as a hip replacement. The former is achieved by reducing the stress and strain on the affected bone, essentially sharing the load. The mechanical stabilisation of bones via the implant allows for optimal bone positioning which can be maintained during physiologic loading and thus the implant aids the natural healing process of bone. OIs allow for restored mobility, reduced pain and improving the overall quality of life for millions of recipients the world over [1].

OIs started as simple mechanical devices, however, complications quickly became apparent. There are many factors to consider, such as the physical impact the device has on the bone and

*Corresponding author: Email address: sean.mcginty@glasgow.ac.uk. Tel.: +44 141 3308588
[1]Division of Biomedical Engineering, University of Glasgow, Glasgow, UK.