OPTIMALITY ANALYSIS OF ORTHOPAEDIC IMPLANTS

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Introduction

The number of arthroplasties has increased in orthopaedic registers and it is estimated to increase even more in the coming years. No class of orthopaedic implants has been proposed proving its everlasting life span. Classes of implants are categorized according with its instrumentation and actuation features controlling failures. Non-instrumented passive implants are the class of implants without instrumentation and active mechanisms. Instrumented implants have only been designed to collect data *in vivo* for research issues [Graichen, 1999; Damma, 2010]. However, only instrumented passive implants have been designed so far. No active implants have been implanted. Only selfprotective surface coatings have been proposed in order to design non-instrumented active implants [Parvizi, 2007]. The use of mechanical actuation systems, to control bone formation surrounding the implant, is the only methodology proposed to design instrumented active implants with the ability to prevent aseptic loosening [Reis, 2012].

We hypothesize that active implants ensure performance optimality preventing failures, whereas passive implants are not able to fully control the implant's life span.

Methods

The algebras of the operations of instrumented passive implants, non-instrumented passive implants, instrumented active implants and non-instrumented active implants were identified, namely their mechanical features, supply and measurement operations, analysis of physiological states and failures, therapeutic actuations, communication and command operations. The architecture, configurations and controllability of each class of implants were researched. An optimality analysis of these implants was conducted using the Pontryagin Maximum Principle [Sussmann, 1990]. The necessary and sufficient conditions for optimality were studied by analysing the existence of t-extremal presynthesis in the control structure of the implants' operation.

Results

From this proof-of-concept study, one can conclude that: (1) it is impossible to ensure optimal trajectories from states of failure to states of without-failure for instrumented passive and non-instrumented passive implants, whatever their architectures, the implants' optimization, rehabilitation protocols or surgical procedures; (2) if optimal trajectories between states of failure and states of without-failure exist, then both instrumented active implants and non-instrumented active implants comprise suitable architectures to implement them.

Discussion

This research proves that the implants' architectures must comprise active therapeutic systems, biological or non-biological, in order to perform optimal performances.

Although instrumented implants have been only purposed as an accurate method to overcome the inaccuracy of numerical and analytical biomechanical models, their architectures can evolve in order to overcome failures ensuring performance optimality. Important breakthroughs can be carried out if research is conducted to design instrumented active implants with the ability to monitor failure-specific molecular markers and with the ability to implement controlled biological therapies. The greater the number of therapeutic and diagnosis systems, the greater the number of trajectories ensuring that a desired physiological state target is achievable from the current states of failure.

References

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