1 INTRODUCTION

The replacement of worn or diseased bones and joints in orthopaedic surgery can massively reduce pain and enhance quality of life for the patients. Worldwide, bone and joint surgery is growing fast because life expectancy is rising, the population in industrialised countries is ageing while aiming to maintain a physically active life style, and a rapidly growing number of people in emerging and developing countries can financially afford orthopaedic procedures. In acknowledgement of these demands, the president of the USA has announced the first ten years of the new millennium as the “Bone and Joint Decade” to give new impetus to a worldwide movement focusing on musculoskeletal health.

More than one million surgeries per annum worldwide make hip joint replacements the most frequently performed orthopaedic operation. A high success rate and a huge improvement in mobility and pain post-operatively makes hip joint replacement the most successful surgical procedure in orthopaedics. However, an increasing number of implants fail prematurely because life expectancy of the population has increased and patients lead more active lifestyles resulting in higher implant loads. In addition, patients of a younger age and with a wider range of medical conditions are undergoing hip replacement. The higher failure rate of old, less advanced primary implants requiring revision today and a significant number of re-revisions mean that in some countries the number of revisions is nearly as high as the number presented for primary joint replacements. Considering the far higher cost of revisions, their financial impact on the health systems is enormous. Being a more complex surgical procedure performed on less healthy and older patients, the success rate of revisions is lower than for primary replacements. In order to improve the clinical success of revisions and to limit the socioeconomic impact, revision hip surgery as a relatively new orthopaedic field still demands intensive research.

Revision joint replacements are different and more complex surgical procedures than primary operations because they involve the removal of the old implant and must deal with the problem of bone loss commonly associated with failed primary implants. Impaction grafting is the only popular revision technique which truly addresses bone loss. It uses morsellised allograft bone chips from donor femoral heads which are impacted into the bone deficient femoral canal or acetabulum in order to create a mechanically stable and biologically active matrix for the cemented or uncemented fixation of a new stem or acetabular cup. Stability of hips revised by impaction grafting depends initially on the mechanical strength provided by

the densely compacted graft. In the long term it relies on graft revascularisation, resorption and bone remodelling creating a new healthy neo-medullary canal or acetabulum. Initial mechanical stability not only secures original implant fixation but it limits micromotion to levels required for osteoconductive processes and offers potential long term stability even without bone remodelling. Thus initial mechanical stability is paramount for the clinical success of impaction grafting.

The complex technique of impaction grafting is manually performed and thus a highly variable procedure which is considered to be a major reason for the variable success rates of clinical outcomes. Due to the popularity of impaction grafting and other surgical techniques using bone grafts, demand for femoral heads has outstripped supply and forced the development of synthetic bone graft extenders or replacements. This study aims to investigate how initial mechanical stability in impaction grafting as the prime condition for clinical success depends on differently prepared bone grafts, varied impaction process parameters and the use of potential ceramic graft extenders and bone/ceramic mixes. For this task, several experimental designs and protocols have been developed and extensively applied to provide a broad analysis of mechanisms, conditions and parameters relevant in impaction grafting. As part of an international research programme, the focus was on the femoral impaction grafting. The tasks of this research work are summarised as follows:

- Development of basic test designs and protocols to identify reproducibly fundamental properties of bone grafts and extender materials relevant in impaction grafting.

- Compilation of a property database for a variety of differently prepared human grafts, potential experimental xenografts and a range of ceramic graft extenders both pure and in bone graft mixes.

- Design of an experimental model and test protocol for endurance testing the initial stability in impaction grafting with variable process parameters, well controlled reproducibility and in-vivo like graft loading.

- In-vitro testing of initial stability for a variety of bone grafts, bone/ceramic graft mixes and varied impaction process parameters in order to reference the stability of experimental bone grafts and bone/extender mixes to the gold standard allograft, to define a ceramic property window for optimum stability and to identify critical impaction process parameters.

- Comparison between fundamental graft properties defined during basic graft testing and the stability performance identified during endurance testing.