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Human femur fracture by mechanical compression: Towards the repeatability of bone fracture acquisition

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ABSTRACT

The increase in life expectancy combined with greater bone fragility over the years is causing a rise in the bone fracture cases. Femur fractures are the most important due to their high mortality rate. This multidisciplinary work is carried out in this context and focuses on the experimental reproduction of human femur fractures by compression. We describe a sequence of steps supervised by orthopaedic surgeons for the correct arrangement of specimens on the system set up to perform the experiment. The device applies force by compression until the human bone is fractured. All tests performed have been monitored and evaluated from different knowledge perspectives. The results obtained have demonstrated the repeatability of the fracture type in a controlled environment as well as identifying the main features involved in this process. In addition, the fractured bones have been digitized to analyze the fracture zone to recreate and evaluate future simulations.

1. Introduction

With the increase in life expectancy, it has become more common to find cases of hip fracture, since the slightest trauma can cause a fracture in fragile bones [1]. Over the years, as bone fragility increases, a fracture of this type becomes an injury with a serious raise of mortality and sequelae for the population. Recent studies indicate how the data vary by country, but estimates that 18% of women and 6% of men will be affected by a fracture. The number of fractures is expected to increase from 1.26 million in 1990 to 4.5 million in 2050, despite the halt in world population growth, but aging is also occurring [2]. Smith et al. [3] analyzed the factors which increase mortality after hip fracture surgery. The estimated mortality rate is between 5% and 10% in the first month and multiplies over the recovery period. Therefore, in this study we will perform the experiment on femurs since it is the most important fracture in the elderly and one of the most fractured bones.

Even though a growing number of technologies help to improve both recovery and surgery, further progress is needed in this area. Fracture area studies allow to improve and validate the development of tools for automatic fracture reduction as well as the development of simulators for the training of future surgeons and the planning of a fracture reduction [1–4].

Consequently, to properly feed these simulators with valid fragments, fractures and other input parameters, a real mechanical process is required as a ground truth. For this purpose, it is necessary to obtain accurate data on the phenomena involved in the fracturing process as well as bone models that enable the reproduction of a real clinical case. Therefore, the aim of this study is to research the repeatability of cadaveric human femurs fractures by mechanical compression to support these tools. Specifically, our proposal evaluates the generation of hip fractures within a controlled and supervised environment. A whole system has been designed to perform a compressive load on eight human femurs in a full standing human position until their fracture.

This research is a result of a multidisciplinary collaboration between the University of Jaén (Computer Science, Mechanical Engineering and Health Sciences Departments) and the Department of Orthopaedic Surgery of the Hospital Universitario de Jaén. The work focuses on the study of femur fractures in the proximal end segment using the whole bone. The design of the system should also take into account the type of fracture and adequate load and rate of compression for its purpose.

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