Development of a Novel Augmentation Pattern of Femoroplasty to Prevent Hip Fracture—Using Finite Element Methods

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Introduction: Hip fractures are one of the most challenging medical problems in the geriatric population, often leading to significant morbidity and mortality; Approximately 30% patients died within the first year after suffering a hip fracture. Additionally, hip fractures impose an enormous economic burden on the health care system. The present preventive strategies include physical exercises, the use of hip protectors, and an array of pharmacological agents. Nevertheless, many issues associated with the use of such agents, e.g. cost, side effects, and patient compliance, can inhibit their efficacy. A logical solution is to develop a prophylactic minimally-invasive surgical intervention to increase the strength of the proximal femur. Femoroplasty, injection of bone cement to proximal, is one of the most promising candidates.

However, Femoroplasty is still at the stage of biomechanical testing. The beneficial effects of femoroplasty in reinforcing bone strength have been determined. But in these studies considerable amount of cement was used, which may cause thermal necrosis of the femoral head during cement hardening. In addition, these augmentation patterns are not consistent with each other and difficult to control. Therefore, the development of a well-directed and controlled cement augmentation with less cement at strategic areas is essential to minimize the biological interference and to maximize the mechanical benefit.

In this study, a CT-based finite element model (FEM) of femur was established to analyze the high risk region of hip fracture during a sideway falling and to develop the suitable augmentation patterns.

Methods: A three-dimension finite element femur model was generated based on the CT scanning data of a healthy volunteer. The cortical bone and trabecular bone was tied constrained. The interface between femoral head and femoral head connection was face-to-face, and the distal femur was fixed with boundary conditions. The material properties of osteoporosis bone and cement were assigned to cortical and trabecular bone and bone cement, respectively. Five augmentation patterns: superior augmentation, medial augmentation, lateral augmentation, femoral calcar augmentation and perpendicular to intertrochanteric fracture line were simulated in this model (figure 1). And the sideway fall on greater trochanter was imitated with linear FE calculation.

Results: The FEA results indicated that the risk region was at the superior lateral side of femoral neck and then the medial side of proximal femur before augmentation (figure 2). Compared to other patterns, femoral calcar augmentation was able to reduce the area of risk region with a smaller mise principle of elements (figure 3).

Discussion: This FE model could clearly predicate the risk region of hip fracture; and it was helpful for selection of the prophylactic strategies. Furthermore, the femoral calcar augmentation pattern was the best choice to reduce the risk of hip fracture, amongst all these groups.
Significance: This established FE femur model will be used for the optimization of femoroplasty pattern, which will help the development of femoroplasty.