COMPUTATIONAL EVALUATION OF INFULENCE OF STEM ORIENTATION TO LONG-TERM STABILITY IN TOTAL HIP ARTHROPLASTY

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Introduction

It is necessary to examine the compatibility of prosthesis to be used for the bone of individual patient prior to the operation of total hip arthroplasty (THA). Preoperative planning of stem size selection, stem positioning and cutting of femur for THA have been investigated mainly from the viewpoint of geometrical fitting between medullary cavity and stem. It, however, is well known that bone changes its structure in response to mechanical stimuli on it. Mechanical condition around interface between bone and stem governs long-term stability of hip prosthesis by bone remodeling phenomenon. Stem positioning error from the preoperative planning due to incorrect surgical operation is another important problem relating to the long-term stability. In this study, influence of stem orientation to long-term stability is computational evaluated using a finite element model of different stem orientation.

Methods

Voxel finite element analysis was performed for 6 different CT datasets. The first dataset came from the post-operative scan of the stem implanted in the femur of a patient operated by an experienced orthopedic surgeon. Other five datasets were artificially constructed by referring to the scan and deviating the rotational stem orientation of 1 to 5 degree in the transversal plane. THA plannings were carried out by referred to the compatibility between the shapes of the stem component and the femur based on individual 3D-CT images [Otomaru et al., 2008]. The boundary conditions for daily loading were considered for three stance states of one-legged, abduction and adduction [Kwon et al., 2010]. Results of FE analysis were evaluated in terms of equivalent strain based on mechanostat theory [Frost, 2003]. The range of strain is distinguished for four strain windows for disuse, physiological, mild overload and pathological overload. Bone resorption considered in the disuse and the pathological overload window is a direct cause of bone loss and is the primal concern with the stem stability after THR. In each Gruen zone, evaluated was the resultant proportion of bone volume with strain of disuse and pathological windows [Kwon et al., 2012].

Results and Discussion

Increase of the stem rotation from the optimal orientation decreases the equivalent strain of bone elements in Gruen zones 1 and 7 (Figure 1). It was observed that the distal-medial part of the stem was less attached to bone as to the increase of rotational deviation from the optimal. Reduced equivalent strain levels in Gruen zones 1 and 7 for large rotational deviation associated with an increase of medullar surface area of disuse window, which could lead to bone resorption resulting bone loss around the stem. Interesting is the distribution of equivalent strain along the stem contour in its principal plane. For large rotational deviation, a larger surface of the distal-medial part of stem loses contact with the bone, as it is shifted more into the marrow space. These will give us a better understanding of the influence of stem orientation on local strain in stem-surrounding bone and can be useful information for surgeons in planning a total hip arthroplasty procedure.

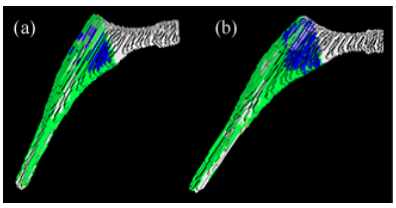

Figure 1 Equivalent strain plot of bone elements surrounding stem surface for different stem orientations. (a) optimal planning by expert surgeon, (b) deviation of anteversion +5°.

References

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