The effect of the wear rate on impingement failure confirming the relation between impingement failure and wear of the acetabular liner surface based on finite element simulation

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ABSTRACT – In this study, an impingement failure analysis was performed on acetabular liner rim of an artificial hip joint (AHJ). A commercial finite element method software package was used to simulate local impingement on the acetabular liner rim (ALR) due to wear depth variations (wear rates) inside the acetabular liner surface (ALS). The results show that wear rates of the ALS can increase the risk of impingement on the ALR.

1. INTRODUCTION

One of the main problem for total hip arthroplasty (THA) patients during their daily activities is dislocation [1]. Two types of dislocation can be distinguished: early dislocation and late dislocation [2]. In general, the early and late dislocations are mostly related to the impingement between the neck stem with the ALR and to wear of the ALS, respectively [2-3]. For the early dislocation, impingement is induced by the range of motion (RoM) limitation of the THA patient's AHJ. The excessive or inordinate activities can induce higher RoM and cause the impingement. Activities of the THA patients as well as its implication to RoM and impingement have been reported. Sugano et al. [4] presented the measurement of RoM for Western and Japanese style activities. Recently, Saputra et al. [5-6] found that impingement and dislocation are predicted to be occurred in picking up activities for the inclination and anteversion combination of the acetabular liner cup of 45°and 15°, respectively.

In addition, after total hip revision, it is found that the wear rate in the late dislocation can increase the impingement. It is indicated that wear of the ALS is sometimes followed by failure on the ALR, based on visual inspection of the orthopedic specialist. Based on clinical data, Tanino et al. [7] found that acetabular liner articular geometry, which the depth of the articular surface is relative to the ALR, is related to the prevalence of dislocation. Using finite element analysis, Scifert et al. [8] showed that in every millimeter of the increased head center inset, the peak moment resisting dislocation increases 5.8%.

Based on literature review, it can be concluded that the wear of the ALS causing the impingement cannot be avoided. However, the wear rate of the ALS can be predicted theoretically, so the impingement which caused by wear rate also can be predicted by considering the wear rate mentioned. In addition to it, this research will be focused on the relation between wear rates inside the ALS and the impingement on the ALR.

The aim of this paper is to study the effect of the wear rate of the tribological contact of the ALS – femoral head (FH) interaction against impingement failure on the ALR. In this study, impingement is simulated using a commercial finite element method software package by varying wear depth inside the ALS, based on specific wear rates obtained from literature.

2. METHODOLOGY

2.1 Investigations and Hypothesis

The acetabular liner is placed between the acetabular cup and the FH in the unipolar AHJ. Based on the visual investigation to the acetabular liner revision obtained from Orthopedic Hospital Soeharso in Indonesia, both the ALR damage and wear inside the ALS were found.

Wear of the ALS causes impingement between the neck stem and the ALR. In addition, the increased wear depth based on specific wear rates obtained from literature will increase the impingement.

2.2 Finite Element Analysis

The working condition of the AHJ was evaluated, then simulated three-dimensionally (3D) with 28 diameter FH, using a commercial finite element (FE) code, see Figure 1. The FE analysis was carried out by assuming that the model is 3D, linear, static, and isotropic material. The material properties of acetabular liner and FH are obtained from literature [9]. The applied load and direction are also obtained from the Dowson's experiment [9], where the loads are applied at the center point of the FH. All the degree of freedom at

the outer surface of the acetabular liner cup is constrained. The simulation is conducted in three steps: creating the artificial wear on the ALS, giving the force on the acetabular liner by the FH, and rotating the FH from neutral position to the impingement in order to represent the flexion movement. The wear depth obtained from literature [9] is used as wear depth variation in the artificial wear step.

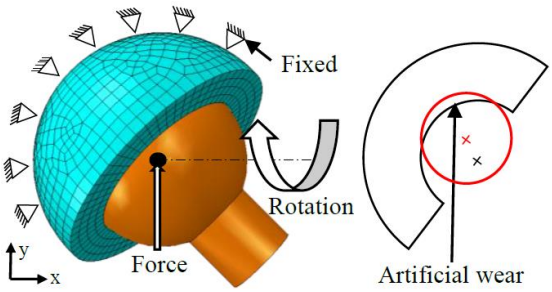

Figure 1 the 3D model of the acetabular liner against the FH include the applied load, constrained, mesh, rotation direction and artificial wear location.

3. RESULTS AND DISCUSSION

Figure 2 shows the impingement angle as a function of the wear depth inside the ALS. It can be explained that the wear inside the ALS has contribution to the impingement on the ALR, where the increasing wear inside the ALS causes the impingement to occur faster.

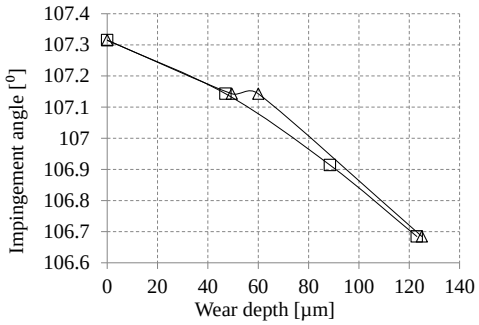

Figure 2 The impingement angle occurrence on the ALR as a function of wear depth.

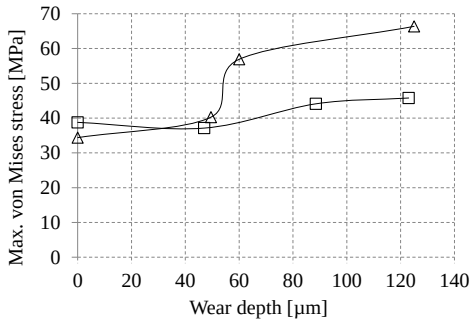

Figure 3 The von Mises maximum stress on the ALR during impingement as a function of wear depth.

Figure 3 presents the von Mises maximum stress of the impingement contact as the wear depth function on the ALS. Based on Figure 3, the von Mises maximum stress will increase along with the increasing wear depth. It means that the damage rate of ALR is proportional with the increase of the von Mises maximum stress. These results have successfully confirmed the previous research [7-8].

4. CONCLUSIONS

This study investigated impingement failure on the ALR using Finite element simulation. The 3D solid model of the acetabular liner was used for the FE analysis under the defined boundary conditions. To obtain relation between the wear rates inside the ALS with impingement on the ALR, wear depth variation was performed based on specific wear rates obtained from literature. The results confirm that increasing wear rates inside the ALS will increase impingement effect on the ALR.

5. REFERENCES

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