INTRAOPERATIVE SOFT-TISSUE TENSION MEASUREMENTS DURING TOTAL HIP ARTHROPLASTY

Higa, M; Tanino, H; Ito, H; Matsuno, T; Sato, T; Banks, SA

1University of Hyogo, Himeji, Japan, 2Asahikawa Medical College, Asahikawa, Japan, 3University of Florida, Gainesville, FL

Senior author banks@ufl.edu

[INTRODUCTION] Dislocation continues to be a common complication of total hip arthroplasty (THA). Many factors affect the prevalence of dislocation after THA, including soft tissue laxity, surgical approach, component position, patient factors, and component design [1]. Restoration of soft tissue tension around the hip joint has been thought to be a crucial factor in preventing dislocation after THA, and recent studies have suggested the dislocation mechanisms without prosthetic or bony impingements and the soft tissue might play an important role for dislocation after THA [2, 3]. There are several intraoperative maneuvers that can be employed to assess both soft-tissue tension and limb lengths, including the shuck test. However, there have been no clinically useful objective measures of testing soft-tissue tension around hip joint after THA.

We have developed a sensor-instrumented modular femoral head to measure soft-tissue tension and force direction during surgery. The objectives of this study were to apply this sensor instrumented modular head during surgery and to measure soft-tissue tension and direction with changing hip positions.

[MATERIALS AND METHODS] Two subjects were analyzed during surgery using the sensor instrumented modular head: a 77 year old female (136cm height, 40kg weight) receiving left THA due to OA, and a 65 year old female (151cm height, 76kg weight) receiving right THA due to OA. Both patients provided written informed consent and the study protocol was approved by the institutional review board. Patients were operated by the same surgeon using a posterolateral approach without trochanteric osteotomy, and were provided hybrid THA (4-U; Nakashima Medical, Okayama, Japan [4]). After all components except the real femoral head were placed, the sensor-instrumented head was attached to the neck of the femoral stem. The soft-tissue tension and direction was measured from full hip extension to 90° flexion. After measurements, the head was replaced with the final 26mm metal femoral head. The postoperative courses of the patients were uneventful.

The sensor-instrumented modular head was composed of two metal parts made of stainless steel with four pressure sensors (FlexiForce A201-100, Tekscan, Inc., South Boston, MA). This 26mm head was designed to measure the resultant hip force dynamically (Fig. 1). The head is attached to the neck of the femoral stem, instead of real femoral head or trial head during surgery. Sensors were placed on the faces of a cube-shaped recess, so that three mutually perpendicular components could be measured: for example, #4 sensor measure $\theta=0$, $\phi=0$ direction component of an applied force. Sensor output voltage ($V_i$) was found to respond linearly to the applied force components ($F_i$) that was directed perpendicular to the sensor surface. If an arbitrary load $F$ ($[F_1, F_2, F_3]$) was applied, each force components $F_i$ was described as follows,

$F_i = |F| \sin \theta \sin \phi$, $F_2 = |F| \cos \theta \sin \phi$, $F_3 = |F| \cos \theta \cos \phi$.

From $V_i$ from each sensor, the applied load can be calculated. Then the load components ($[F_1, F_2, F_3]$) were transferred to the pelvic coordinate system considering the thigh position, the neck angle, and the stem anteverision and alignment. Benchtop calibration showed mean absolute errors of force magnitude were 2.87%, and mean absolute angular errors were 1.44°.

[RESULTS] In both cases, dynamic soft-tissue tension and direction was successfully measured during surgery using the sensor-instrumented modular head. In both subjects, the soft-tissue tension (resultant hip force) was largest with the hip extended, with forces decreasing in flexion. The minimum soft-tissue tension occurred around 40° flexion. The largest soft-tissue tensions were 326 N and 438 N for the first and second subjects, respectively (Fig. 2). From extension to flexion, the mediolateral component force did not change significantly, but the supero-inferior and anterior-posterior components did change significantly with flexion. With hip flexion, the superior component decreased and the posterior component increased. With hip extension, the direction of soft-tissue tension was superior, moving posterior at 90° flexion (Fig. 2).

[DISCUSSION] We successfully measured the soft-tissue tension and resultant hip force direction in two patients during surgery using a sensor-instrumented modular head [5]. The results of these initial trials show relatively large force magnitudes (300-450N) and a resultant force direction that changes with hip flexion. These measures should provide useful insight to dislocation mechanisms, especially posterior dislocation. We believe this objective information on intraoperative soft-tissue tension will be useful for enhanced understanding the dislocation mechanisms, and ultimately decrease the incidence of dislocation after THA.

---

Fig. 1 A schematic illustration of the sensor-instrumented modular head developed in this study. The cone angle $\theta$ and the polar angle $\phi$ define the load direction.

Fig. 2 Data on magnitude and orientation of hip force. The results for the first patient (top) and second patient (bottom) are shown. The measured sensor outputs were transformed to the pelvic coordinate system. Positive values indicate anterior, superior and medial directions, respectively.