Thermoelastic Stress Analysis For Surface Stress Imaging Predicts Clinical Outcome Of The Total Hip Arthroplasty

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Introduction: The initial stress distribution on the femur after a total hip arthroplasty (THA) influences the bone remodeling, and thus the clinical results. Using thermoelastic stress analysis, we are able to analyze and visualize in three dimensions the changes in the sum of the principal stresses based on temperature changes at the bone surface.

To elucidate differences in the in vitro surface stress distributions on femurs after THA for different stem designs, we conducted thermoelastic stress analysis of specially shaped stems that had an anterior and posterior flange, and compared the resulting distributions in the model system with the clinical outcomes.

Methods: The THA stems (Bicontact and Excia, B. Braun, Melsungen, Germany) were inserted into synthetic femurs (Pacific Research Laboratories, Vashon Island, WA, USA). A 0.27 Hz sinusoidal compressive load (20-1000 N) was applied to the femoral head for the thermoelastic analysis, and surface stress distribution images were acquired in four planes. The stem positions were obtained using computed tomography (CT) imaging after insertion were transferred to those obtained using CT before insertion. The bone reactions around the Excia stem were analyzed as a clinical assessment using X-ray images obtained from patients 2 years after the THA (43 cases, 45 hips). The contact patterns on the CT images were analyzed using a modified Gruen zone system wherein the Gruen zones were divided into anterior (A) and posterior (P) portions on the CT images.

Results: Thermoelastic analysis identified compressive stress in the medial portion and tensile stress in the lateral portion of both stems. The stress distribution on the Excia was more proximal than that on the Bicontact stem. In addition, the stresses were not distributed over the most proximal areas of either stem (Fig. 1; upper panel: Bicontact; lower panel: Excia). The contact patterns on the CT images showed that the Bicontact and Excia stems were in contact with the cortical bone at the middle and distal portions, but the Excia stem was also in heavy contact with bone in zone 2A (Fig. 2; upper panel: Bicontact; lower panel: Excia). The clinical assessment of the Excia showed first-, second-, and third-degree stress shielding (SS) in 32%, 65%, and 3% of the hips, respectively. On CT, the stem was in contact with the cortical bone at the middle and distal portions in most cases, and at zone 2A in all cases (see percentages by zone in Fig. 3).

Discussion: The mechanical results suggest that the load is transferred mostly to the middle portions, and slightly to the distal portions, of the Excia stem. Clinically, the Excia showed first- or second-degree
SS in most cases, with few cases of severe SS (SS was found only in the proximal portions in cases of second-degree SS).
The load appeared to be appropriately transmitted because the stem was in contact with the bone at zone 2A in all cases.

**Significance:** Thermoelastic stress analysis provided full-field visualization of the surface stress distribution on femurs after THA, and the mechanical results were correlated to the clinical results. Therefore, thermoelastic stress analysis can be used during the development of new stem designs to predict the clinical results of use.

![Thermoelastic analysis of Bicontact and Excia](image)
Fig. 2 The contact patterns on the CT images
Fig. 3: The % of cases by zone where there was contact between the Excia stem and cortical bone.