Optimization of proximal fit with shorter stem

An anterior approach during total hip surgery can be advantageous for its less invasive technique as compared to a more traditional posterior approach. However, the less invasive technique necessarily results in a surgical window with restrictive geometry which complicates insertion and placement of longer femoral components. DJO Surgical designed the TaperFill femur with a shortened overall length to facilitate insertion with an anterior approach and an anatomically congruent, tri-taper profile to maintain stability and prevent subsidence.

Method:

The proximal body shape was designed to optimize fit along the medial-anterior aspect of the proximal femur. To evaluate the design concepts, concept CAD files were virtually implanted into femur geometry represented by ADaMs™ standardized femur models for 5 sizes: mean, ±1 standard deviation from the mean, and ±2 standard deviations from the mean. The ADaMs models were constructed from a database of 73 male and female femur CT scans (mean age 67.5) taken from Northern Europe. Three of the individual femur scans used in the data base were selected for validating the fit of the proposed implant geometry.

Location of cross sections where implant and femur fit was evaluated.

An evaluation of the concept designs was also performed to evaluate the initial mechanical stability of the concept designs. The femur models were first virtually broached to form a cavity that was the negative of the proposed design concept. The implant geometry was fit into the cavity and the assembly transferred to Ansys where a frictionless contact analysis was defined. A single load vector corresponding to the peak load magnitude and direction during gait was used to load the implant neck. Percent micromotion relative to the Linear Stem was calculated from displacement of the implant and cancellous bone cavity at a point medial and a point lateral as an indication of implant stability.

Finite element analysis used to evaluate stability of implant concepts during gait cycle.

ADaMs Femurs are mathematical idealizations that represent the sampled femur population as discrete geometries.

Fit of the design concepts was evaluated at standardized cross sections through the ADaMs models by measuring the length of congruent contact between the stem and the inner surface of the cortical shell. The distance was normalized to the distance measured for the Linear® hip stem and then reported as a % change from Linear.
Results:

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<tr>
<th></th>
<th>% MEDIAL MICROMOTION</th>
<th>% LATERAL MICROMOTION</th>
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<tbody>
<tr>
<td>RELATIVE TO LINEAR</td>
<td>RELATIVE TO LINEAR</td>
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<tr>
<td>SHORT STEM, DUAL TAPER</td>
<td>8.2</td>
<td>9.8</td>
</tr>
<tr>
<td>TAPERFILL</td>
<td>-93.6</td>
<td>-69.9</td>
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ADAMS MODEL

- MEAN SIZE

<table>
<thead>
<tr>
<th>ADAMS MODEL MEAN SIZE</th>
<th>-2 STANDARD DEVIATION MODEL</th>
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<tr>
<td>57.3% INCREASE IN CONGRUENCY VS LINEAR</td>
<td>40.6% INCREASE IN CONGRUENCY VS LINEAR</td>
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Discussion:

From the analysis of the cross sectional plots, three dimensional concept designs were developed that

1. had reduced overall length
2. were congruent with the cortical bone in the medial-anterior aspect of the femur
3. consisted of a tri-taper design to minimize subsidence risk

Due to variations in bone geometry with size, concepts built using the mean sized model were not always best fits for the other sizes, but by scaling the design concepts for the ±1, ±2 sizes optimal shapes were developed to provide maximum congruency without interference across all sizes.

While a highly congruent implant shape was a design goal, the most highly congruent shape was not necessarily the optimal shape. A design that is highly congruent below the resection may present problems during insertion as the surgeon would be unable to visually confirm proper sizing and placement of the implant at the resection plane. The final Taperfill design had a congruency that was 57.3% better than the Linear stem, easier to insert with an anterior approach, and provides visual feedback to the surgeon for sizing and placement.

To accommodate an anterior approach, a reduced length stem was desired, but it was recognized that simply cutting the stem on an existing implant could decrease initial stability thereby delaying or inhibiting bone growth. Therefore, the new femur design would make use of increased proximal body congruency and tri-taper approach to maximize initial stability. Using the FEA model, micromotion between the implant and the broached bone was assessed for peak loading during the gait cycle. The clinically successfully Linear stem was used to benchmark excellent performance while a short dual taper stem (Linear that was artificially shortened) was used as an indicator of minimal performance. The final TaperFill concept, with its proximal conforming, tri-taper design had predicted micromotion less than one-third of Linear.

Example of predicted micromotion in the concepts (red arrows). Scale exaggerated to show detail.

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1 Interface Micromotion of Uncemented Femoral Components from Postmortem Retrieved Total Hip Replacements