A Structural Analysis of Proximally Coated Tapered Cementless Femoral Stems

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INTRODUCTION

Primary, uncemented total hip arthroplasty is becoming the fixation of choice for the vast majority of patients undergoing hip replacement surgery in North America. Femoral stems are typically made of titanium or titanium alloy, often incorporating a proximal bone-ingrowth surface or ongrowth surface throughout the length of the stem. Osseointegration of the stem requires an osseoco nductive/inductive surface and initial stability. Excessive relative motions between the implant and bone may lead to fibrous tissue formation, compromising osseointegration.1 Although a stiff stem may lead to long-term bone loss due to stress shielding, lower stiffness will increase the interface micromotions.2 Selection of a particular implant design is usually a matter of surgeon preference, and the size is selected based on comparing an A-P pelvis x-ray with an outline of the stem sizes on a template. The objective of this study was to determine basic geometric and structural parameters of some of the more common cementless tapered femoral stems in order to gain a better understanding of their initial clinical performance both from a technical and fixation standpoint.

METHODS

Templates were obtained for four uncemented femoral stems: Accolade (Stryker), Profemur (Wright), Taperloc (Biomet) and Tri-Lock (Depuy). All of these stems are classified as proximally coated tapered stems permitting ease of insertion due to their minimized lateral shoulder. All sizes were scanned and saved as images on a PC, and each image was analyzed using ImageJ (US National Institutes of Health). The image scale was first calibrated using the full scale on the template and the ‘Set Scale’ feature. Measurements were then made of the stem length, and at various locations the width of the stem (anterior view) and thickness of the stem (lateral view), as well as the height between the locations (Figure 1). According to beam theory, the deflection of a beam in bending is proportional to (1/EI) where E is the material elastic modulus and I=tw^3/12 for a rectangular cross section of thickness t and width w; here EI is a measure of stiffness for bending purely in the coronal plane and neglects rounded corners. The modulus was assumed to be 114 GPa for the Profemur, Taperloc and Trilock stems; the Accolade stem was assumed to have a modulus of 85.5 GPa due to the manufacturer’s claim of a 25% more flexible alloy. Stem thickness ratios were calculated as w/t at different locations as a measure of lateral vs. AP fill of the femur. Stem taper ratios were calculated as the ratio of w or t at various locations. In the absence of normative data on the shape of the proximal femur, it was assumed that the width at level A primarily determines the size of stem for a particular patient. This is the most lateral point of the implant and this width was therefore chosen as the stem size to compare between implants of different manufacturers.

RESULTS

Stem stiffness at levels A and B are shown in Figure 2. The stiffness at level B showed increasing differences between manufacturers with larger stem sizes. Some representative measurement ratios are shown in Figures 3 and 4. The distal stem taper is the ratio of w at level A and C (Figure 3); the ratio of t/w (e.g. at level B, Figure 4) is a measure of relative filling in the AP and lateral directions.

DISCUSSION

Various geometric and structural characteristics of four cementless stems were determined. Ratios of geometric features assess the filling of the internal cavity of the femur which may affect the stability of the implanted stem. The structural measures assess the flexibility of the stem under loads. It was found that amongst grossly similar stems, the actual geometry of proximal shoulder differs significantly which in turn influences the stiffness of the stem, which may vary widely at different levels (Figure 2).

The actual performance of an uncemented implant depends on many patient and surgical factors with these measures representing only one aspect for the successful fixation of the femoral stem. Other complex factors such as compatibility between the shapes of the stem and surface contours of the bone or bone ingrowth into a specific surface cannot be accounted for in this study. However such basic measures are easily obtained and can provide some insight to elucidate differences in order to guide them for implant selection as well as interpretation of clinical performance. For example, the Accolade stem has exhibited large, early subsidence patterns2 and inhibiting osseointegration.1 The smaller taper (Figure 3) may also play a role in the initial fit and stability of the stem. These could be further investigated through primary stability testing of stems of different moduli or detailed finite element studies.

REFERENCES