Acta Orthop Scand 1988;59(6):638–642

Primary fit of the Lord cementless total hip

A geometric study in cadavers

Jan-Willem Schimmel and Rik Huiskes

Two Lord prostheses, bilaterally implanted in cadavers, were sectioned. The contact areas between bone and prosthesis were studied and measured using a specially developed reproducible method. Primary fixation of the femoral components appeared to be based principally on wedging of the prosthetic stem in the femoral shaft with a rather small contact surface. In both acetabuli the screw threads of the rings were only marginally in contact with the acetabular bone.

The primary fixation of hip prostheses is considered of decisive significance for a solid cementless fixation (Lord et al. 1979, Morscher 1983, Engelhardt 1984). Adequate primary fixation should be mechanically stable immediately after the operation, with extensive bone contact, through which stabilizing osteogenesis can lead to a reliable long-term fixation.

We have studied the primary fit of the Lord total hip.

Material and methods

Two Lord (PUP) prostheses were implanted by the inventor bilaterally in a cadaver according to the standard technique. The prosthetic material consists of a cobalt-chromium alloy. The prosthetic collar is designed to contact the greater trochanter laterally and to rest horizontally on the femoral calcar to effectuate stress transfer in the proximal femur (Lord et al. 1980). The whole stem surface has fluted, polarized corrugations.

The acetabular component consists of a cobalt-chromium threaded ring containing an interchangeable polyethylene liner . The threaded cup has a truncated-ellipsoidal shape (Lord et al. 1983). The outer surface contains alternately four and five screw threads. Both implanted prostheses in our specimens were identical: stem diameters 15 mm, stem lengths 180 mm, threaded ring diameters 58 mm.

Biomechanics Section, Department of Orthopedics, University of Nijmegen, The Netherlands

Correspondence: Prof. Dr. Rik Huiskes, P.O. Box 9101, N-6500 HB Nijmegen, The Netherlands

Before the specimens were processed, a general visual inspection of the fixation was made, and radiographs were taken from several angles.

The femora were positioned in a rectangular, prismatic Teflon box and imbedded in epoxy resin. They were then sectioned with a diamond saw perpendicular to the longitudinal stem axis (Figure 1).The rectangular sides of the epoxy served as local references for each slice. In determining the slice level, the horizontal lower edge of the prosthetic collar was chosen as zero. Twenty-five slices were made from the right femur and 21 from the left femur.

The cross-sections of both femora and acetabula were photographed and contact radiographed. The femoral contact radiographs were measured using an Aristomat coordinate digitizer (Aristo Werke AG, Hamburg, FRG). Points on the circumference of the stem were digitized, and the cross-sectional contour length was calculated. The amount of stem circumference in contact with bone was expressed relative to the circumferential stem contour length.

The prosthetic stem was divided into medial, lateral, anterior, and posterior quadrants, based on the geometry of the section located 106 mm below the collar (Figure 2). In this section, the locations of the femoral area center of gravity and the stem area center of gravity were calculated. The linea aspera center was identified and its position measured. Based on these three points, the four quadrants were determined and extrapolated to obtain a local anatomic reference system in all the sections. The amount of stem circumference in contact with bone was then also evaluated per quadrant.

The acetabuli were sliced in pie sections, perpendicular to the free edges of the acetabular rings, through the centers of the cups (Figure 3). The location of each section was identified on radiographs, also taken per-

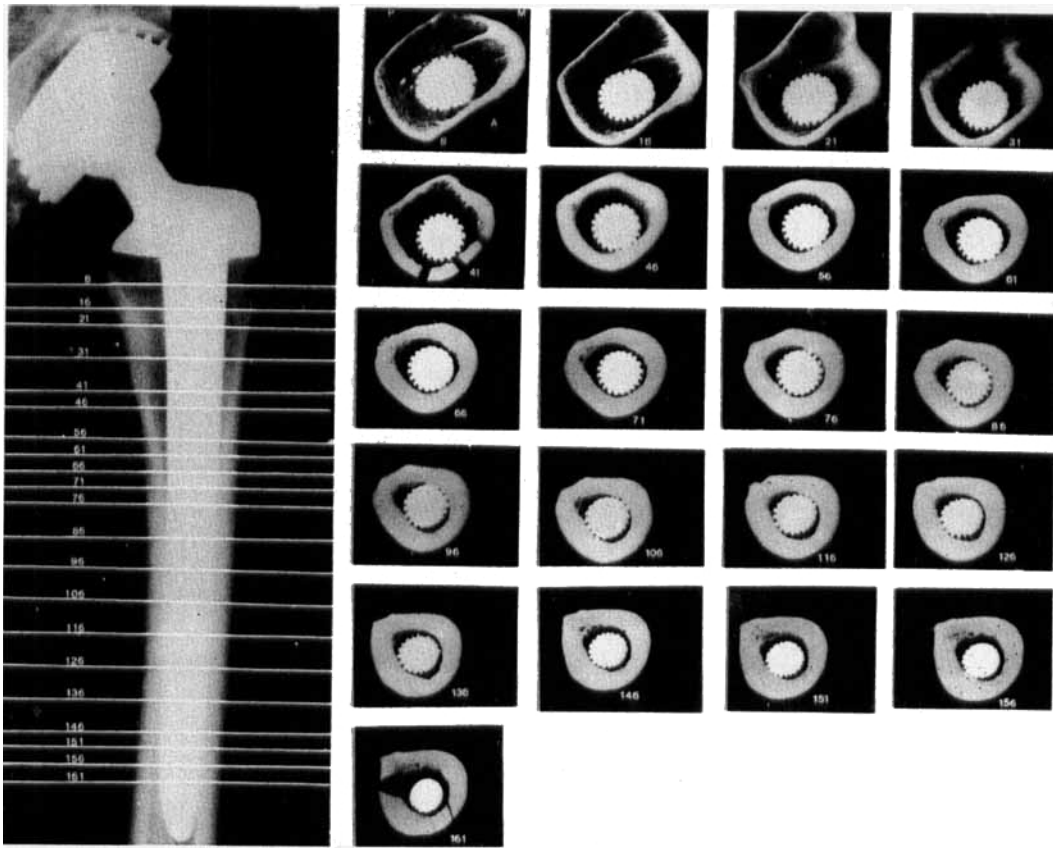


Figure 1. Frontal radiograph of the left femur with 21 contact radiographs of the cross sections. A = anterior, M = medial, P = posterior, L = lateral.

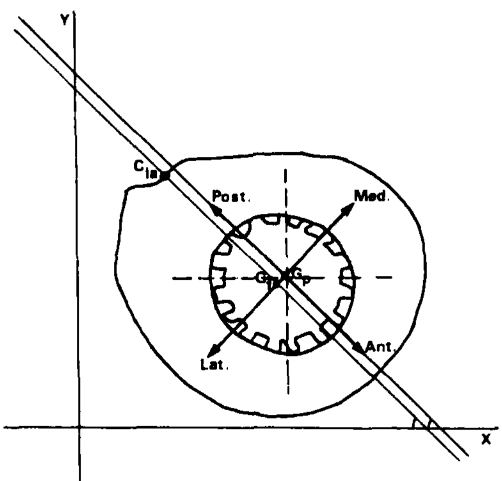


Figure 2. The assessment of four anatomic quadrants relative to the stem in a slice 106 mm below the collar. The stem area center of gravity (G_p) serves as the base point for this local reference system. Its orientation is based on the line through the linea aspera center (C_{la}) and the area center of gravity of the bone (G_b).

pendicular to the edge of the rings, and expressed as an angle relative to a line through the cup center, perpendicular to a reference line. This reference line was drawn on the radiographs as the tangent to the anterior gluteal line and the posterior surface of the ischial bone. The relation between the radiographs and the actual slicing procedure was maintained with the use of thin copper wires, fixed on the free edge of the cup, intersecting the cup center. Sixteen almost identical slices were made from both acetabula; the anatomic location of each slice could be reconstructed.

Photographs of the acetabular sections were used to digitize the contours of the stem and the bone, and to determine the contact configuration. Results were expressed as the part of the cup surface contained within the acetabular dome (Figure 4), the percentage of bone contact within that part, and the amount of screw threads in contact with bone.

The standard errors of the measurements, determined by four times' repeated measurements by 2 persons in two slices of each femur and acetabulum, were 1.1–2.1 percent for femoral stem contact and 0.8–1.2 percent for acetabular cup contact.

Acta Orthop Scand 1988;59(6):638–642

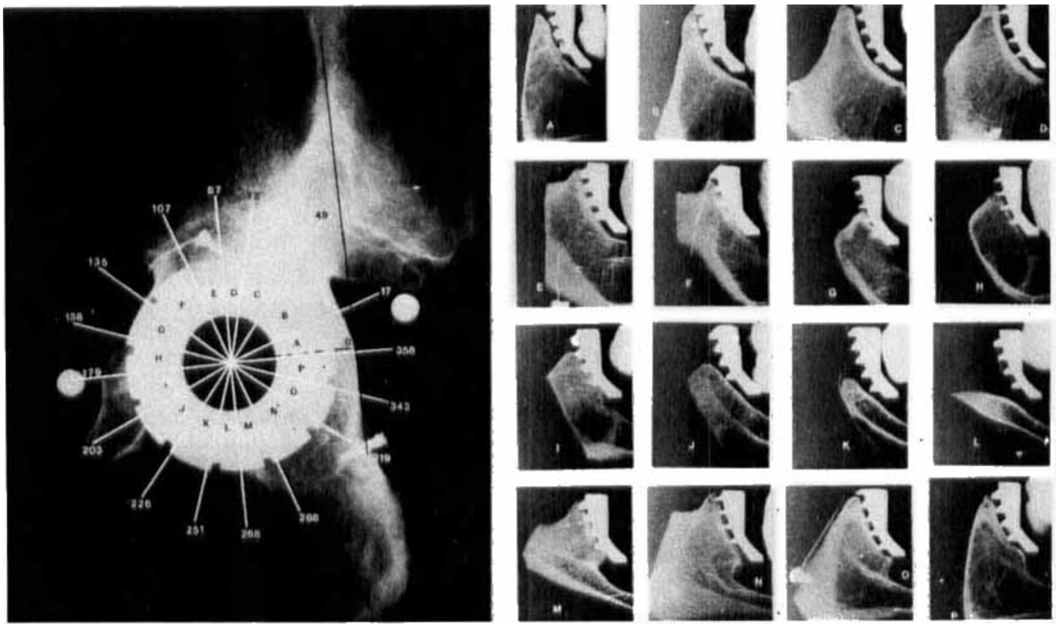


Figure 3. Radiograph of the left acetabulum perpendicular to the free edge of the threaded rings with 16 contact radiographs of the sections.

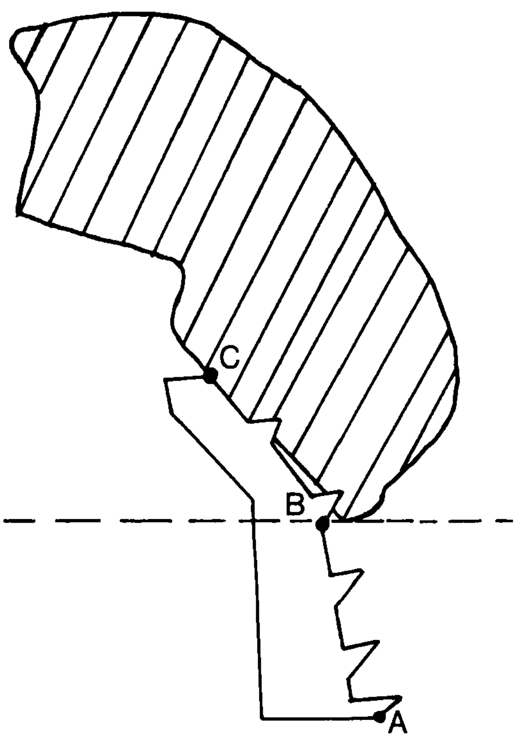


Figure 4. Schematic section of acetabulum and threaded ring with the measured surface contours. The ratio BC:AC determines the part of the cup surface contained within the acetabular dome.

Results

Visual and radiographic examination of the specimens did not show any contact between prosthetic collar and proximal femur in any location. A fracture in the left greater trochanter was apparent.

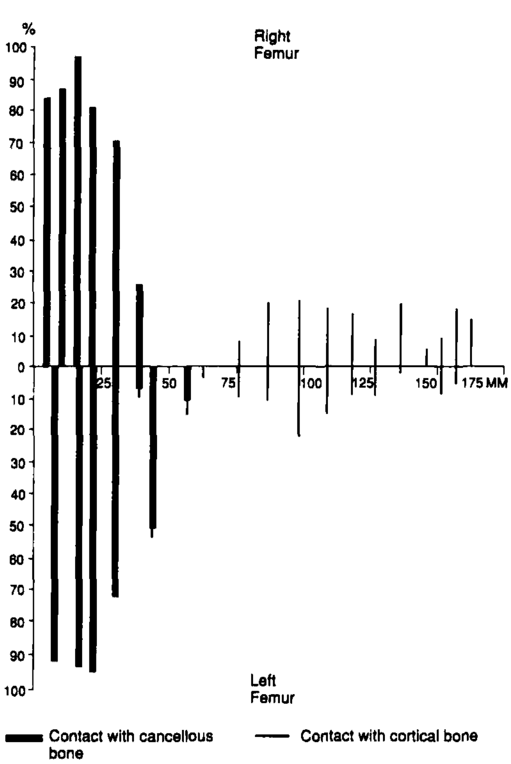
Almost full contact with cancellous bone was realized in the proximal 25 mm of the prosthetic stem, gradually decreasing to zero at the 50-mm level (Table 1). Contact with cortical bone did not increase over 25 percent, and was less at most levels.

The stem contact configuration per quadrant was not very consistent in the two femurs. As can be readily seen in the slices of Figure 1, the contact was spotty, in particular with cortical bone. In the right femur, most cortical contact occurred in the anterior and lateral quadrants. In the left femur anterior contact was virtually nonexistent; conversely, more contact was found here on the medial side.

The results for the acetabula were quite consistent for both sides. The cup was only fully covered by the acetabulum on the superior and posterior inferior regions, as is also evident from the slices in Figure 3. On the anterior side, only 50–75 percent of the ring surface was contained within the acetabular dome.

On the surface within the acetabular dome, only 0–12 percent was in actual contact with bone on the right side. On the left side, similar values were found, with some exceptions of 75–100 percent somewhat

Table 1. Percentage of the stem circumference in contact with bone at the section levels



superior to the anterior side (see also slices F, G, and H in Figure 3).

The most comprehensive evaluation follows from the number of screw threads in contact with bone (Figure 5). This number varied between 3 and 4 in the superior/anterior and inferior/posterior regions, and between 0 and 2 elsewhere.

Discussion

The contact measurements showed that the design objective of perfect fit in the immediate postoperative stage was not realized in the specimens investigated. On the femoral side, contact between collar and calcar, medially, and the collar and greater trochanter, laterally, intended in the design (Gosset 1949, Lord et al. 1979, 1980), was absent on both sides. Although intimate contact between the proximal stem and cancellous bone was found, the contact between stem and cortical bone in the diaphysis was limited to a few regions only, indicating that the stem was basically wedged within the intramedullary canal. Most of the contact regions were found in the femoral isthmus, in the medial and lateral quadrants. The contact configuration in the sagittal plane was largely determined by the shape of the lateral bend. In this plane, 3-point cortical contact can be realized in principle (proximal/anterior, middle/posterior, and distal/anterior), but this was not obtained in our specimens: in the right femur the proximal/anterior contact point was absent, and in the left femur the distal /anterior contact point.

On the acetabular side the lack of intimate contact between threaded ring and bone was surprising. Although the design objective is to self-tap the threads in the bone, this was not realized. The threads were more or less wedged in the acetabulum, between the posterior/inferior and anterior/superior faces, where usually about three threads were in contact with bone, but seldom cut inside the bone. In the superior region where most of the stress transfer to the ilium would occur (Huiskes 1987), only marginal contact was measured. In several slices taken from the anterior/inferior part, no contact was found at all.

Evidently, seen on a general scale, fits of cementless prostheses will vary. These variations occur on several levels. In the method assessment applied here, the variation, i.e., the standard error, was found to be small. Some variation may also be expected depending on the quality of the surgical technique and on the variation of bone sizes. In this respect, our results must be regarded as typical, based on the selection and implantation by the designer of the implant, rather than general or average. Another variation is due to prosthetic design, and in this respect only one type was evaluated.

Although the results of the measurements were clear and generally consistent for both specimens, they must

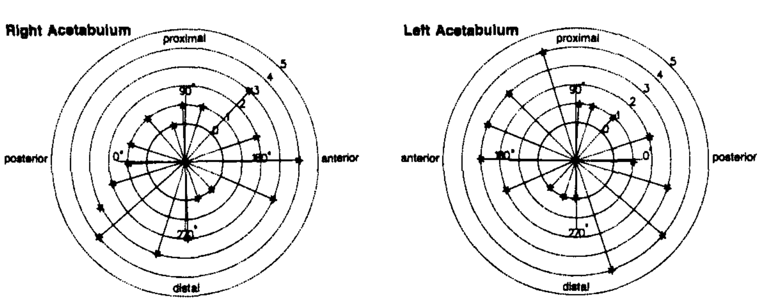


Figure 5. Numbers of threads found in contact with bone at the section levels (for orientation of section locations, compare Figure 3).

be interpreted with care. The limited contact in the femoral diaphysis does not necessarily imply that the femoral component would not be mechanically secure. Although it is believed that exclusive cancellous bone contact is important in secondary fixation only and contributes little to primary stability (Engh 1983, Seidel 1984), the additional scattered diaphyseal contact points in combination with the extreme length of the stem will probably keep the implant stable. If not, subsidence will most likely lead to a stable position.

The interpretation of the acetabular findings is more difficult. Finite element stress analysis of a comparable threaded cup fixation has indicated that local peak stresses occur in bone near the threads, even if the cup is ideally fixed (Huiskes 1987). In the contact configuration found here, these stress peaks could be many times higher, possibly leading to local failure, micromotion, and gradual loosening.

Evidently, the present findings concern the immediate postoperative situation only. Once bone ingrowth has occurred, this initial contact configuration becomes irrelevant. Postoperative patient evaluation studies are promising in this respect (Lord and Bancel 1983). It would thus be wrong to condemn the Lord prosthesis design based on these findings.

References

Engelhardt A. Causal histogenesis (Pauwels, Kummer) and related biomechanical discoveries as a basis for the cementless fixation of hip prosthesis. In: The cementless fixation of hip endoprostheses (Ed. Morscher E). Springer Verlag, Berlin 1984:21–8.

Engh C A. Hip arthroplasty with a Moore prosthesis with porous coating. A five-year study. Clin Orthop 1983;(176): 52–66.

Gosset J. Présentation d'une arthroplastie de la hanche par prothèse cervico-capitale. Mem Acad Chir 1949;75:800.

Huiskes R. Finite element analysis of acetabular reconstruction. Noncemented threaded cups. Acta Orthop Scand 1987;58(6):620–5.

Lord G A, Hardy J R, Kummer F J. An uncemented total hip replacement: experimental study and review of 300 madreporique arthroplasties. Clin Orthop 1979;(141):2–16.

Lord G, Marotte J H, Blanchard J P, Guillamon J L, Bancel P. Valeur de l'assise horizontale et de l'appui diaphysaire dans la repartition des contraintes du fémur prothese: étude comparative des contraintes exercées en charge sur le femur normal et sur le femur porteur d'une prothese a appui trochantero-diaphysaire madreporique. Rev Chir Orthop 1980;66(3):141–56.

Lord G, Bancel P. The madreporic cementless total hip arthroplasty. New experimental data and a seven year clinical follow-up study. Clin Orthop 1983;(176):67–76.

Morscher E W. Cementless total hip arthroplasty. Clin Orthop 1983;(181):76–91.

Acknowledgements

We gratefully acknowledge the partial sponsorship of Sanortho (Paris, France) in the completion of this work, and thank Professor G. Lord for the specimens.