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Biomechanical factors in loosening of the Stanmore hip

A series of 33 Stanmore total hip replacements with aseptic loosening was compared to a matched control series without loosening. Risk factors were previous hip surgery and osteopenia of the proximal femur. Biomechanical factors, notably varus position of the femoral stem and insufficient cementation, were of significance for the implant loosening. Alteration of the operative technique is recommended, emphasizing a correct valgus or neutral position of the femoral component and improved cementation.

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The purpose of our study was to define reasons for aseptic loosening of the femoral component in total hip arthroplasties by **comparing** a series of patients undergoing revision arthroplasty due to loose prosthetic components with a matched series of patients who did not develop this complication.

Patients and methods

Total hip replacement surgery was performed in 308 patients with 320 hips during the years 1978 and 1979. These cases included 33 revisions of one or both components due to non-septic loosening.

The prostheses were all of the Stanmore standard type with a 29 mm head, a small collar and a 142 mm stem, manufactured from cobalt-chromium-molybdenum alloy (Alivium (R)). At the primary operation, the cement (Simplex P with radioopaque material) was in all cases digitally introduced in the femoral medullary canal without the use of a cement gun or medullary plugging.

In the 33 hips (18 males and 15 females), separate loosening of the femoral stem in 20 cases and of both components in 13 cases was confirmed at revision. Osteoarthrosis was the primary cause of THR in 31 patients, hip fracture in one, and femoral head necrosis due to uremia in one patient. The mean age of the patients at the time of the primary operation was 64 (48–79) years. The time from the primary operation to revision surgery was 36 (4–68) months.

A matched control series was composed of 33 patients of same sex, age, preoperative diagnosis and type of arthroplasty, but with no clinical or radiographical signs of loosening throughout identical periods of observation.

The radiographs were taken with the patients in supine position as antero-posterior and lateral views with the foot upright, but otherwise no standardized radiographic procedures to ensure reproducibility. The groups were compared in order to find factors predisposing to loosening of the femoral stem.

Bone mass and femoral shaft dimensions

As a measurement of the bone mass in the upper end of the femur, the cortical index (Fredensborg & Nilsson 1977) was determined from the preoperative radiographs. This index was defined as the thickness of the calcar femorale in relation to the total width of the femoral neck at its narrowest part. Another bone index was calculated midway along the femoral stem from the total thickness of cortical bone divided by the total width of the femoral shaft after superimposement on the preoperative radiograph. In addition, the thickness of the femoral component was compared with the width of the medullary canal, as measured at the level midway along the femoral stem.

Bone cement

The distribution of the cement was analyzed in the radiographs taken immediately postoperatively. The proximal femur was divided into five zones (Figure 1). The packing of the cement was defined as adequate if all cancellous bone was removed and/or the thickness of the cement mantle was at least 2 mm in more than half of the zone.

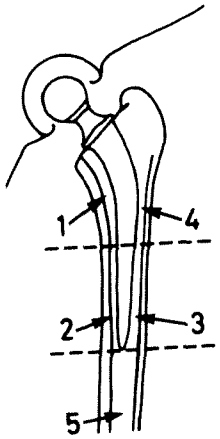

Figure 1. Zones for measuring the quality of cement packing in the upper and lower half and distal to the prosthetic tip in THR.

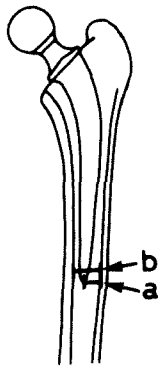

Figure 2. Valgus coefficient: V = a/b. Increased varus position leads to decreased distance a and thus decreased numeric value of the valgus coefficient.

Figure 3. The inclination between the axes of the femoral stem and shaft indicates valgus (left), neutral (middle) and varus position (right) of the Stanmore prosthesis.

Positioning of the prosthesis

The femoral component was defined in the AP-plane according to the valgus coefficient (Figure 2) and to the inclination of the axis of the stem in relation to the axis of the femoral shaft (Figure 3). In the lateral view the axis of the prosthetic neck was related to the axis of the femoral neck, indicating ante- or retroversion. A retroposition coefficient was calculated from measurements of the distance of the tip from the posterior cortex divided by the measured width of the femoral shaft at the same level.

Statistics

A Wilcoxon test for matched pairs was applied for all paired observations, whereas a Chi-square test was applied on 2 × 2 tables.

Results

The body weight in the group including loose prostheses was on average 79 (50–115) kg, as compared to 76 (54–106) kg in the control group. The difference was not significant.

Previous operations had been performed in four cases among the loose prostheses, but in none in the control group ($P < 0.05$, Chi-square test).

The cortical index at the calcar femorale was 0.15 (0.12–0.21) in the group with loosening, as compared to 0.18 (0.13–0.27) in the control group. Loosening thus occurred more often when the calcar bone stock was thin prior to surgery ($P < 0.01$, Wilcoxon test). The cortical index calculated at the level of the middle of the femoral stem was of no significance and neither was the length of the preserved femoral neck.

Cementation technique

Insufficient packing was encountered in 29/33 of the loose prostheses, as compared to 12/33 in the control group (Table 1). Sufficient cementation is clearly important for the prevention of loosening, especially laterally along the femoral stem, as well as medially at the level of the calcar and below the tip of the prosthesis.

The relation between the width of the medullary canal and the thickness of the femoral stem was of no significance, indicating that the actual thickness of the bone cement layer is of less importance, provided it is more than 2 mm.

Table 1. Deficiencies in packing with bone cement related to aseptic loosening in THR

Topographic region	Prosthetic loosening n = 33	Control series n = 33	Level of significance P <
Calcar fem.	7	1	0.02
Fem. stem med.	5	1	0.09
Fem. stem lat.	20	1	0.0005
Prosthetic tip	18	10	0.05
Total	29	13	0.0005

Table 2. Femoral stem position related to aseptic loosening in THR

	Prosthetic loosening	Control series	Level of significance $P <$
Valgus	8	10	0.0005
Neutral	7	16	
Varus	18	7	
Valgus coefficient	0.44 (0.22–0.73)	0.51 (0.29–0.71)	0.06

Positioning of the prosthesis

Varus position was related to loosening of the femoral stem, both when measured in relation to the axis of the femoral shaft and when calculated from the valgus coefficient (Table 2).

Whether the prosthetic neck was long (40.5 mm) or short (30.5 mm) had no relation to loosening. The retroposition coefficient for the prosthetic tip had no importance, nor had the degree of retroversion, indicating that ante- or retroversion of the prosthesis was without implication for the rate of loosening in this series.

Discussion

Aseptic loosening is probably the most common problem in the long-term follow-up of total hip replacement. Comparison between series is difficult because criteria for loosening differ. In our series we tried to avoid problems about the uncertain significance of radiographic loosening by comparing only probands with operatively proven loosening and matching control patients without clinical or radiographic signs of implant loosening.

As risk factors, previous hip surgery and osteopenia of the calcar region were confirmed (Bocco et al. 1977, Chandler et al. 1981, Lindberg & Carlsson 1983, McBeath & Foltz 1979, Stauffer 1982). Opinions differ concerning the importance of the width of the femoral shaft, but we found a wide medullary canal of no significance, as also reported by Lindberg & Carlsson (1983).

The design of the prosthesis probably plays a part in nonseptic loosening (McBeath & Foltz 1979). We confined our study to the Stanmore prosthetic design with a small collar and a rather oval stem shape. In accordance with others (Hierton et al. 1983, Lindberg & Carlsson 1983, Sutherland et al. 1982), we found neither a long neck length of the prosthesis nor the length of the femoral neck to influence the results. This means that in performing the operation no emphasis should be put on preserving the length of the femoral neck or choosing a prosthesis with short neck length; rather, more emphasis should be put on obtaining the correct leg length.

The most important biomechanical factors related to loosening of the femoral stem were varus position of the prosthesis and insufficient cementation proximomedially against the calcar femorale and laterally along the femoral stem. These three factors are obviously closely connected, as varus position leads to shorter distances to the calcar and the lateral cortex and thus less space for the bone cement. Our observations accord well with the majority of publications (Beckenbaugh & Ilstrup 1978, Cotterill et al. 1982, Coudane et al. 1981, Dorr et al. 1983, Harris et al. 1982, Lindberg & Carlsson 1983, McBeath & Foltz 1979, Olsson et al. 1981, Pellicci et al. 1982, Reikerås 1982, Soereide et al. 1982, Sutherland et al. 1982). In addition, we also found the quality of cementation of importance around the prosthetic tip (Lindberg & Carlsson 1983, Olsson et al. 1981), where the majority of the load on the prosthetic stem is transmitted to the bone.

Improvement of the operative technique should thus be emphasized in the application of total hip replacement. In accordance with Beckenbaugh & Ilstrup (1978), the cancellous bone should be removed entirely from the calcar area and the medullary canal, especially inferolaterally, to expose the femoral cortex to sufficient cement bonding.

The cementation technique seems to be a critical point which needs to be improved in order to establish a sufficient cement mantle between the correctly positioned prosthesis and the femoral shaft. It has been pointed out from laboratory tests that voids should be prevented (Oh et al. 1978) and that lamination of the cement or mixing with blood reduces the cement strength considerably (Greenwald et al. 1978).

These investigations have resulted in recommendations to plug the medullary canal prior to cementation, to use a cement gun and even to pressurize the cement (Oh & Harris 1982). In clinical practice, these procedures have proven successful (Harris et al. 1982, Hoogland et al. 1981) and there is no doubt that the bonding strength of the cement is improved by these measures (Oh et al. 1978). In our opinion medullary plugging and the use of a cement gun can be recommended to improve the cement mantle, but we are more reluctant to recommend pressurizing until studies on possibly adverse effects on bone remodelling have been completed.

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