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LOCALIZED BONE RESORPTION IN THE FEMUR IN MECHANICAL FAILURE OF CEMENTED TOTAL HIP ARTHROPLASTIES

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In 70 total hip arthroplasties exchanged because of mechanical loosening of the stem prosthesis, localized bone resorption or scalloping was found in 33 cases. In 19 of the 33 cases the process started at the level of the tip of the stem, which in 15 cases was found to be in direct contact with cortical bone as observed in the radiographs obtained immediately after the primary surgery. In 37 failures without scalloping this metal-to-bone contact was less common. It is concluded that localized bone resorption may occur as a result of mechanical stress and in the absence of deep infection. It is also suggested that the phenomenon might be avoided by proper cementing technique and centering of the tip of the stem, perhaps with the help of a centering device.

Key words: arthroplasty; hip; radiography

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Localized resorption of the endosteal surface of the femur in cemented total hip arthroplasty has for a long time been thought to be caused only by infectious processes (Bergström et al. 1974). However, later investigations (Harris et al. 1976, Charnley 1979, Linder et al. 1983) have demonstrated that these localized bone resorptions, or scallopings, may also occur in cases where infection can be excluded.

There have also been suggestions that wear particles from the joint surfaces may cause a bone-resorbing granuloma if present in excessive amounts (Brinkmann & Heilmann 1974, Revell et al. 1978, Willert et al. 1980). However, the erosions frequently appear isolated at the tip of the stem which makes the suggested mechanism difficult to explain.

Allergic and toxic reactions to cemented metal-to-plastic total hip arthroplasties are probably extremely rare (Deutman et al. 1977, Carlsson et al. 1980, Rooker & Wilkinson 1980, *Brit. Med. J.* Editorial 1980) and could not be made responsible for these relatively common non-infectious scallopings. Thus, there must be another hitherto unknown explanation.

The purpose of this study was to analyze localized endosteal bone resorptions in a series of total hip arthroplasties exchanged because of mechanical loosening.

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MATERIAL AND METHODS

Between 1970 and May 1982, 183 first time exchanges of 179 metal-to-plastic and four metal-to-metal total hip arthroplasties were performed at the Department of Orthopedic Surgery, Malmö General Hospital. Sixty-six of these exchange operations were performed because of proven or strongly suspected deep infection, 17 because of loosening of the socket alone, 12 because of dislocation or subluxation, seven because of obvious technical error at the primary surgery, one because of femoral fracture below the tip of the prosthesis and four because of unexplained pain.

In the remaining 76 cases the exchange operation was performed because of loosening – subsidence and/or varus migration – of the stem prosthesis. This loosening was confirmed in all cases both in the pre-exchange radiographs and at the exchange operation by palpation. In all cases infection could be excluded by multiple negative aerobic and anaerobic cultures (Kamme & Lindberg 1981).

The whole series of radiographs, from the one taken immediately after the primary operation to those taken immediately before the exchange operation, was scrutinized in each of the 183 cases. However, in six cases some of the radiographs were unavailable or were of inferior quality and therefore these cases had to be excluded.

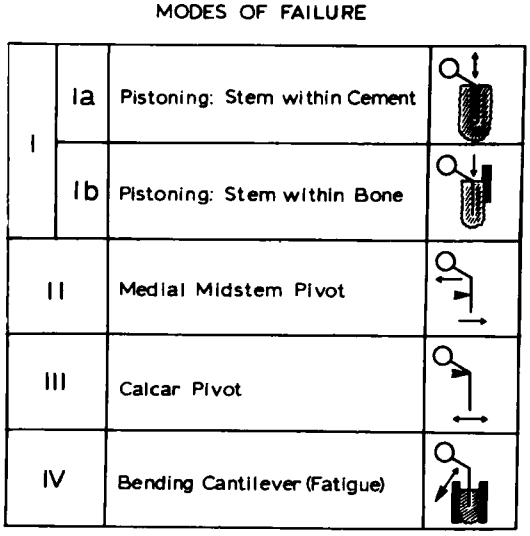
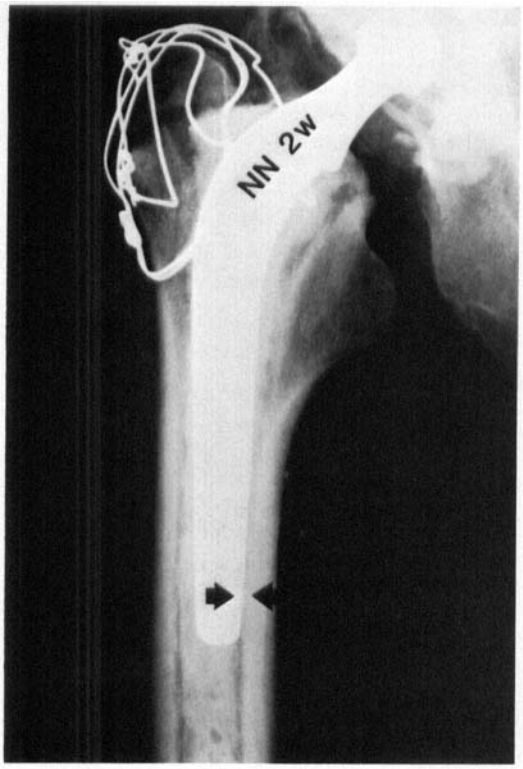


Figure 1. Modes of stem failure according to Gruen et al. (1979) (Reprinted with permission by authors and publisher).

Figure 2. An a–p (a) and lateral (b) view of a Charnley THR 2 weeks post-operatively. Direct contact between the stem and the cortex in both projections.

a



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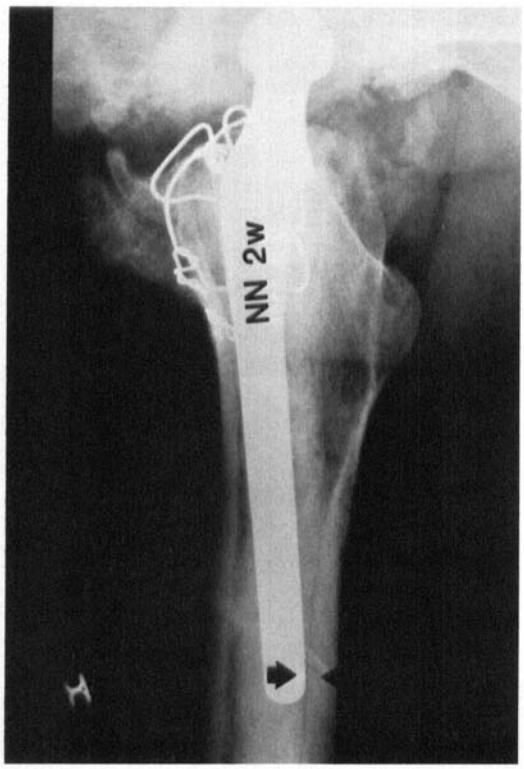

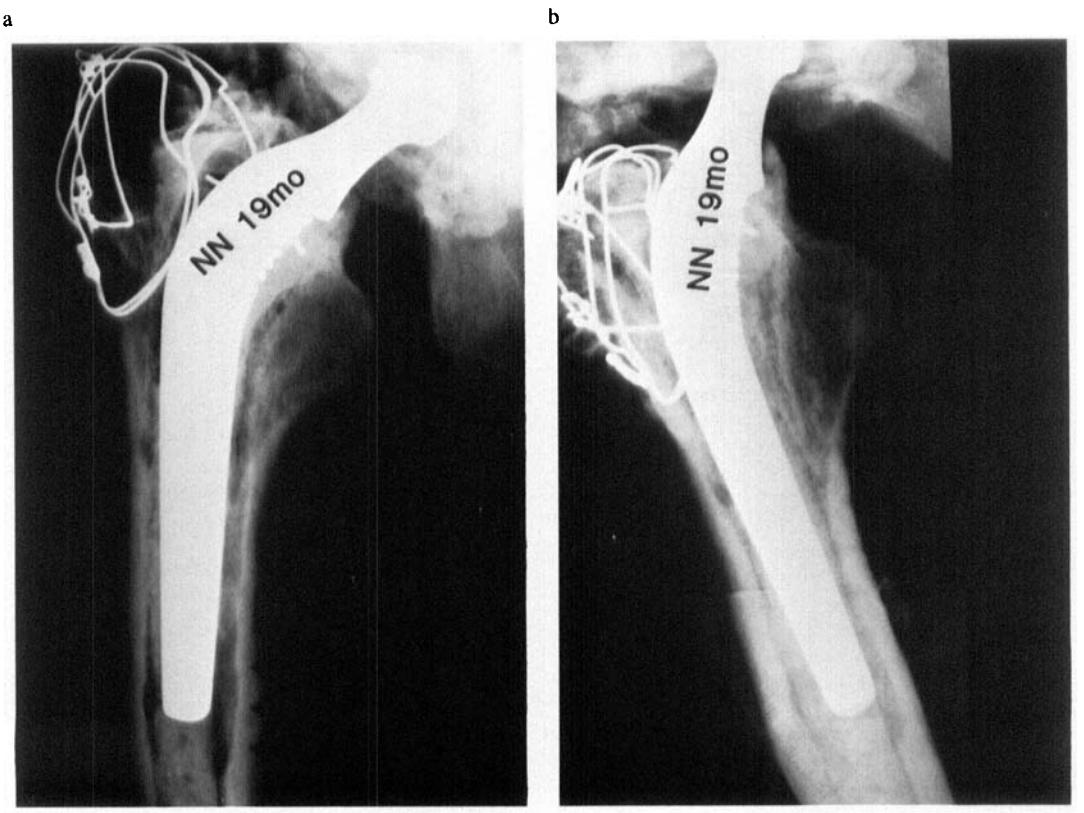

Figure 3. The same hip 19 months post-operatively. The stem has subsided as indicated by the radiolucent zone lateral to the neck-stem junction. In the a–p view (a) a slight *scalloping is seen lateral and* severe *scalloping medial to the tip of the stem. In the oblique projection (b) there is scalloping at the point of previous bone-metal contact.*

After exclusion of cases with deep infection, obvious technical error and insufficient radiographic information, an examination of the technical quality of the primary total hip surgery and the following events was made in the remaining 104 cases.

The "mode of failure" of the femoral stem referred to in the following text is the system introduced by Gruen et al. (1979) (Figure 1). The bone resorption was classified as slight, moderate or severe. Typical examples are illustrated in Figures 2–4. It was also noted in what part of the femur the process started as observed in the a–p or lateral projections.

The time between the primary operation and the exchange operation in the 104 cases included in this study ranged between 10 months and 13 years; average 59 ± 29 months. This time interval did not differ in cases with and without scalloping.

RESULTS

Localized endosteal bone resorptions were observed in 33 out of the 70 cases exchanged because of mechanical failure of the stem. Five cases were classified as slight, 13 as moderate and 15 as severe. Regardless of the region in which the process started, a progress to other parts of the femur was seen in 25 of the 33 cases.

Scalloping starting about the proximal third of the stem

In eight of the 33 cases scalloping was first observed at the medial or lateral part of the proximal third of the stem and in four cases classified as moderate and in four as severe. The "mode of failure" was classified as I a in two cases, mode II in one cases and as IV in five cases. In three cases the tip of the prosthesis was surrounded whereas in another four cases it was not surrounded by bone cement. In one case the radiographs were inconclusive.

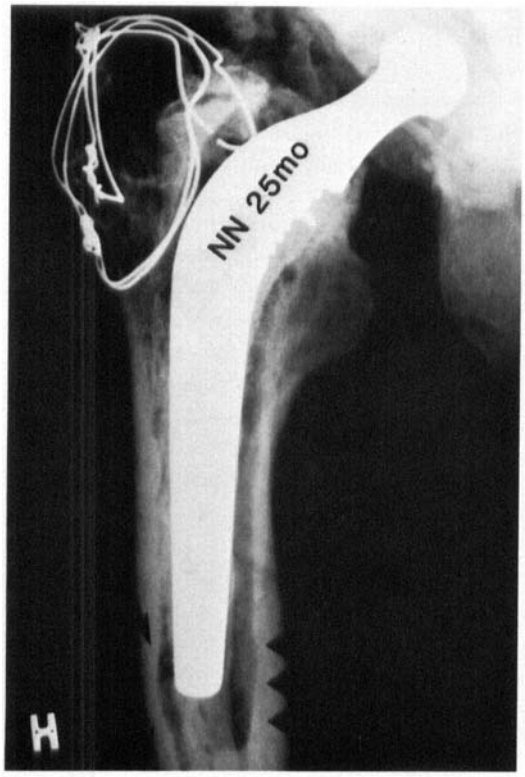

Figure 4. The same hip 25 months post-operatively. The scalloping lateral to the tip of the stem has increased and is now classified as moderate.

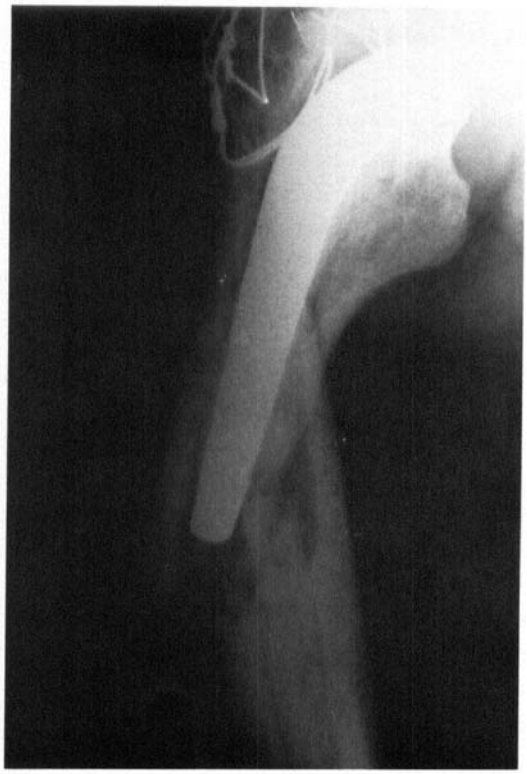

Figure 5. Three years post-operatively the same patient sustained a mild trauma resulting in a fracture at the level of the scalloping.

Scalloping about the middle part of the stem

In only two cases was the scalloping observed to start about the middle part of the stem. In both these cases the process was classified as moderate and the "mode of failure" as I a. The tips of the prostheses were completely surrounded by cement in both cases.

Scalloping starting at the level of the tip of the stem

Scalloping starting at the level of the tip of the stem was observed in 19 cases: five slight, seven moderate and seven severe. In one of the severe cases the patient eventually fractured his femur at the level of the resorption (Figure 5). The "modes of failure" were as follows: in nine cases mode I a, in four cases mode I b, in three cases mode II and in three cases mode IV.

In 15 of the 19 cases the tip of the prosthesis was primarily in direct contact with that part of the endosteal surface where the scalloping first appeared. In three mode I a and one mode IV failure the tip of the stem was primarily surrounded by cement but in these four cases the cement later fractured, the tip and the crushed cement moving towards the place where bone resorption later could be observed to start.

Scalloping in cases with insufficient radiographic information

In four cases with severe scalloping it was not possible to determine in which region the process had started. In three of these cases the tip was surrounded by cement and the "mode of failure" classified as IV. In the fourth case the tip of the stem was in direct contact with cortical bone in

both radiographic projections and the "mode of failure" classified as I b.

Mechanical failure without *scalloping*

In 37 cases, in which the stem of the prosthesis was exchanged for mechanical reasons, no localized bone resorption was observed in the radiographs. The "mode of failure" was classified as I a in 24 cases, I b in two cases, II in two cases and IV in nine cases. In 13 of 35 cases the tip of the stem was in direct contact with the femoral cortex in the radiographs taken immediately after the primary operation, whereas the position of the tip was impossible to determine in three cases. In the remaining 21 cases the tip was seen to lie well away from the femoral cortex in both projections and in 13 of the 21 cases it was completely surrounded by cement, in seven cases not at all surrounded by cement and, finally, in one case partly surrounded by cement.

Stable femoral prostheses

In 34 cases one or both prosthetic components were exchanged because of socket loosening (17 cases), dislocation or subluxation (12 cases), unexplained pain (4 cases) or femoral fracture (one case). With the exception of the patient described below, there were no signs of stem loosening either in the radiograph or on inspection and palpation of the prosthesis at the exchange operation. The position of the stem was acceptable in all but two cases.

The tip of the stem was in direct contact with the cortical bone in seven out of 28 cases in which both the a–p and the lateral projections were possible to evaluate.

In one case revised because of recurrent dislocation a slight localized bone resorption was observed medially at the tip of the stem. The prosthesis had been inserted in valgus position but with the tip of the prosthesis in direct contact with the cortical bone where the scalloping later started. In spite of the fact that the stem was found to be stable at the exchange operation the radiographs revealed a 2-mm subsidence of the stem within the cement and possibly the stem had stabilized itself in a new position. With time the bone resorption progressed to include also the middle part of the femur but was still classified as slight.

In another patient with severe rheumatoid arthritis the socket migrated centrally. In spite of a stable femoral component a slight bone resorption was observed at the proximal part of the femur and later progressed to include also the middle and distal parts.

In still another patient with bilateral total hip replacement, both sockets were exchanged because of loosening. In spite of bilateral stable femoral components, scalloping was seen in the proximal third of both femora, on one side medially and on the other laterally, but without progress to more distal parts of the femora.

DISCUSSION

Localized bone resorption, cystic erosion of bone and scalloping are expressions used synonymously and first described in total hip replacements complicated by deep infection (Bergström et al. 1974). Later on, the same findings have been described in non-infectious loosening of the femoral component (Harris et al. 1976, Charnley 1979). The present investigation demonstrates that the phenomenon is more common than previously thought and occurred in 33 of our cases in which the stem was exchanged because of mechanical failure. The phenomenon is also of real clinical importance because in the majority of our cases the bone resorption could be demonstrated to progress, regardless of where it had started. In one of our cases the femur fractured through such a resorption at the tip of the stem (Figure 5). If the resorption takes place at the upper part of the stem, fatigue fracture of the stem may occur (Charnley 1979, Gruen et al. 1979).

An examination of the radiographs taken immediately after the primary operation revealed that the tip of the stem significantly more often was primarily in direct contact with the cortical bone in cases with the combination of mechanical failure and scalloping at the tip than in failed stems without scalloping. In all of the cases with distal scalloping where the tip of the stem

primarily was surrounded by cement, fracture of the cement later occurred, the tip of the stem moving towards the region where the bone resorption was observed to start.

The findings of the present study would support a mechanical explanation of the phenomenon of scalloping. In scalloping at the tip of the stem, 15/19 of the cases showed a direct metal-bone contact, a figure which does not favour the idea that fragmentation of the cement is the primary cause of the lesion but rather secondary to instability. The findings suggest that high local stresses or micromovement at the metal-bone interface are created and that the bone responds by resorption. It may be that such conditions are more readily generated by the unprotected small-surfaced metal tip.

The mechanical theory is also favoured by the fact that localized bone resorption has not been observed in perfectly stable and symptomless hips in our long-term follow-ups of non-infected total hip arthroplasties (Carlsson & Gentz 1980).

Endosteal resorption has been described in cement-free implant systems such as the silicone Swanson prosthesis (Hagert 1976) and bone resorption adjacent to mobile metallic implants is well-known. High stresses to bone can be generated via bone-cement, as could be the case in our scallopings starting about the proximal third of the stem. The two cases with the scalloping starting about the middle part of the loose stem are more difficult to explain. The implication of our findings is that mechanical phenomena can be responsible for scalloping. This study does not incriminate bone cement as such or the principle of cement anchorage as the cause of scalloping, but indicates that cementing technique and positioning of the stem are crucial.

The mechanical theory is further borne out by the histological picture (Linder et al. 1983) which lacks features specific for scalloping. Areas of scalloping consist of loose connective tissue with an abundance of macrophages and fibroblasts but few lymphocytes. The bone appears vital and there is often new bone formation at the bottom of the pits. In some cases there is evidence of wear particles of cement or of polyethylene from the socket, but such findings are inconstant and do not differ from other areas without scalloping and may very well be secondary to loosening.

This study does not imply that metal-to-bone contact predisposes to loosening, even though other studies suggest that loosening is more common in such cases (Olsson et al. 1981). Nor does it imply that distal metal-to-bone contact necessarily gives rise to distal scalloping. However, it does indicate that stem failures characterized by distal scalloping are very often associated with metal-to-bone contact. As this type of bone resorption was progressive in the majority of the cases it is important to eliminate its cause. This study would suggest that a centering device around the tip of the stem might be valuable in creating better distal cement support. While this may not eliminate loosening it might hopefully reduce the likelihood of distal scalloping.

CONCLUSIONS

From this investigation it might be concluded that:

1. Localized bone resorption is a common phenomenon seen in cortical bone in stem loosening.
2. It may occur as a result of mechanical stress and in the absence of deep infection.
3. Localized bone resorption at the tip of the stem occurs more often when the stem primarily is in direct contact with cortical bone or where such contact is established later as a consequence of cement fracture and migration of the stem.

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