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Radiological Image of the Femur After Cementless Total Hip Replacement in a 3-Years' Follow-up

Radiologiczny obraz kości udowej po wszczepieniu bezcementowej endoprotezy biodra w ocenie 3-letniej

INTRODUCTION

Cementless hip prosthesis has been widely used both in treatment of osteoarthrosis of the hip and aseptic loosening of the cemented prosthesis. The aim of the present study was to analyse radiological changes evolving in the femur after implantation of cementless smooth-surfaced total hip prosthesis in patiens with good clinical outcome. We analysed changes at the bone-implant interface and in the cortical bone. We made an attempt to establish radiological criteria for primary and secondary prosthesis fixation.

MATERIAL

From a series of prostheses implanted between 1984—1987 we selected 70 patients with unilateral Bichat III-type prosthesis (Fig. 1) in whom primary osteoarthritis was an indication for surgery. We evaluated comparable radiograms of the hip performed immediately and at the 6th, 12th, 18th, 24th and 36th month after surgery. Only the radiograms without migration of the femoral part of the prosthesis were analysed.

METHODS

The following radiological patameters were analysed: cortical contact, radiolucent line at bone-implant interface, osteocondensation line, mean thickness of the cortical bone in the individual segments and the bony pedestal. The radiological image of the femoral stem of the prosthesis was divided into segments according to Gruen (9), establishing eight segments for analysis. The metaphyseal region included two segments I and VII — diaphyseal region comprised segments II, III, IV at, IV med, V and VI. The cortical contact was defined as the ratio of the length of prosthesis stem adhesion to the cortical bone, to the length of a given segment, expressed as per cent values (Fig. 2).

The radiolucent line is the lucency at the implant — cortical bone interface. The osteocondensation line is an osseous reaction occurring externally to the radiolucent line. The bony pedestal is an osteoblastic reaction localized beneath the tip of the femoral stem of the prosthesis (Fig. 3). The bony pedestal thickness was measured in its medial, lateral and central part. Mean values of the above mentioned parameters were calculated from three measurements taken with slide calipers. Statistical significance of the results was tested by an F-test of an analysis of variance using Statbaz set.

Fig. 1. Total hip prosthesis Bichat III

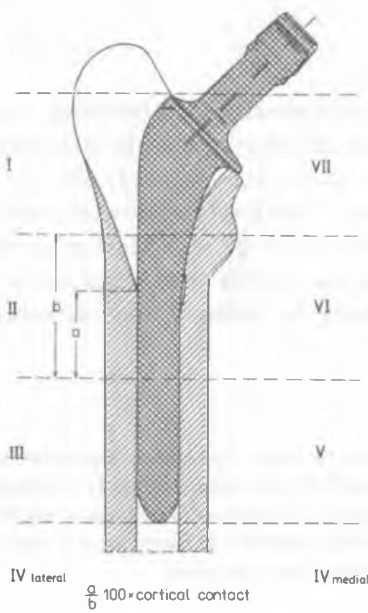

Fig. 2. Diaphragmmatic representation of the cortical contact and segmentation of femur. Description of cortical contact in the text. Segmentation of the femur according to Gruen

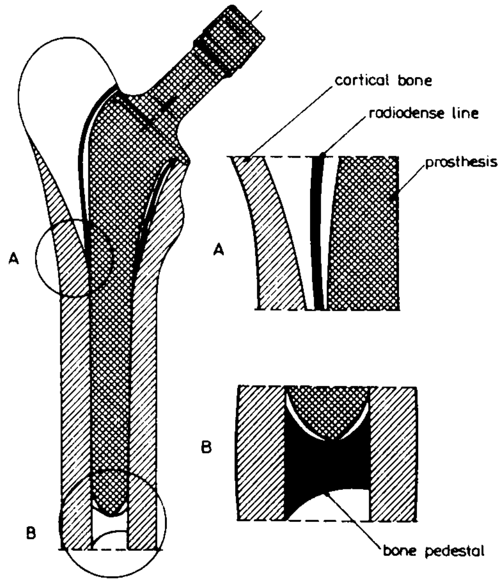

Fig. 3. Diaphragmatic illustration of radiolucent and radiodense lines and bone pedestal

RESULTS

Four types of radiological changes in the femur have been described. Radiological evolution type I (18 cases) is characterized by a gradual increase in the cortical contact in segments III, V, VI, VII up to the maximum level of 79% in segment V. The radiolucent line is present in about 50% of the cases, its width does not exceed 0.2 mm, except for segment I, in which it increases to 0.8 mm and then decreases to 0.5 mm. The osteocondensation line is also found in about 50% of the cases, its width does not exceed 0.2 mm, only in segment I it increases from 0.4 to 1.1 mm. The cortical thickness does not change significantly with time and ranges from 0.2 to 9.9 mm in the individual segments. The bony pedestal is present in about 40% of cases and its thickness increases with time at the lateral side, up to the maximum of 3.3 mm.

In radiological evolution type II (12 cases) the cortical contact increases slightly (at 20%) in the metaphyseal region — segments I, VI, whereas a considerable increase has taken place in segments II, III, V (40%). The radiolucent line in segment I rises to 0.8 mm and then stabilizes, whereas in segments II, VI it rises to 0.4 mm and decreases to 0.1 mm. The radiolucent line is absent in segment VII. The osteocondensation line is also absent in segment VII, whereas in the remaining segments its development is dynamic, being the most clearly visible in segment I where it exceeds 2 mm in width. The cortical thickness increases markedly to 10.4 mm in segment VII, while in the remaining segments it is stable ranging from 6.8 mm to 9 mm. The bony pedestal develops in all cases and increases with time up to 20.8 mm at the lateral side of the prosthetic stem.

In radiological evolution type III (25 cases) the cortical contact decreases initially, whereas in the course of time it increases up to 62% in segment III, 43% in segment V, 50% in segment VII. The radiolucent line is present in all the segments achieving the maximum thickness of 1.3 mm in segment I. The osteocondensation line also develops in all the segments with maximum thickness of 1.5 mm in segment I. The cortical thickness increases significantly in all the segments except for segment I, with the maximum value of 9.8 mm in segment IV lat. The bony pedestal develops in all cases, increasing with time up to maximum thickness of 12.2 mm at the lateral side.

In radiological evolution type IV (15 cases) the cortical contact increases slightly in all the segments, with the maximum value of 78% in segment V. The radiolucent line widens gradually in segments I, II, VI, VII with the maximum value of 1.3 mm in segment I, whereas in segment III and V its width takes 0.1 mm. The osteocondensation line becomes visible in segments I, II, VI, VII increasing to the maximum of 1.2 mm in segment I, while it is absent in segment III and V. The cortical thickness increases considerably in segments IV med and IV lat up to the maximum value of 10.6 mm in segment IV lat, whereas in the remaining segments ranges from 4.0 to 9.4 mm without any significant temporal changes. The bony pedestal is present in 13% of the cases thickening slightly up to 3.3 mm at the lateral side of the prosthetic stem.

DISCUSSION

The radiological parameters analysed in our study constitute a morphological expression of processes occurring at the bone-implant interface as a result of local mechanical and biological factors (1—3, 5, 8, 10—14, 17, 18). The study shows a differentiated pattern of radiological changes in the osseous tissue, in the assessed group of patients, after implantation of cementless hip prosthesis. We distinguished four types of evolution of the radiological image of the femur, after implantation of the prosthesis over 3 years. In type I we observed weak dynamics of radiological changes. It was characterized by a slight increase in the cortical contact of the prosthetic stem and unstable development of narrow radiolucent and osteocondensation lines. The widths of the radiolucent and osteocondensation lines increased only in the region of the greater trochanter. No significant changes in the cortical thickness were found. The bony pedestal developed not uniformly and it was narrower than in the remaining types. Those radiological changes resulted, most probably, from an even distribution of mechanical stresses, lack of micromovements at bone-implant interface and stability of the prosthetic tip. We think that that type of radiological changes in the femur indicates primary total prosthetic fixation i.e. primary metaphyseal-diaphyseal fixation. In type II dynamics of radiological changes was marked. We found initially high cortical contact in the metaphyseal segment and its gradual increase in the diaphyseal segment. The radiolucent line and osteocondensation line were prominent in the diaphyseal region, whereas they were absent in the calcar region. The bony pedestal showed high dynamics of its development and reached the highest value in this type of radiological evolution. The radiological changes described above are associated with good metaphyseal fixation and transmission of forces in the hip joint through the proximal segment.

The concentration of stresses in the calcar region led to an increased cortical thickness according to the Wolffs law. A considerable development of the bony pedestal could indicate an initial lack of stabilization of the distal prosthetic segment with its secondary fixation due to osteoblastic response. We believe, that this type of radiological evolution indicates primary metaphyseal and secondary diaphyseal prosthetic fixation. There is a certain similarity to "calcar pivot instability" observed in cemented prostheses according to Gruen (9). In type III radiological changes were also dynamic. We found a considerable increase in the cortical contact of the prosthetic stem in all the segments, excluding segment I. The increase in the cortical contact occurred primarily due to widening of the osteocondensation line which had been ultimately integrated with the cortical bone — i.e. corticalization of the radiodense line. The radiolucent line gradually regressed at the end of the follow-up period, and the cortical thickness slightly incereased in all the segments excluding segment I mainly due to above mentioned corticalization. The bony pedestal was characterized by a considerable increase in its thickness. This type of radiological evolution may, in our opinion, result from insufficient proximal and distal adhesion of the prosthesis to the bone. An initially small cortical contact increases due to osteoblastic reaction at the bone-implant interface, fixing secondarily the prosthesis.

The described radiological changes may be caused by surgical factors, osteoinductive effects of titanium (1, 6, 7) and other less known local factors (4). We think that this type of radiological changes in the femur is consistent with the secondary metaphyseal-diaphyseal prosthetic fixation. In type IV of radiological evolution, dynamics of the development of the cortical contact and radiolucent line was low. Instead, we found dynamic development of the osteocondensation line in the metaphyseal segment and a considerable increase in the cortical thickness in the diaphyseal segment of the femur. The bony pedestal was characterized by a slight increase in its thickness. This type of radiological evolution may be indicative of a strong fixation of the prosthesis in the diaphyseal segment with its weak bond in the metaphyseal segment. The increase in the cortical thickness in the diaphyseal segment and weak development of the bony pedestal in our opinion indicate transmission of resultant hip joint forces to the femur, through the distal part of the prosthesis, and its good diaphyseal stability. Secondary osseous response in the metaphyseal segment of the femur leads to proximal prosthetic fixation. We think that this type of radiological evolution is caused by primary diaphyseal and secondary metaphyseal fixation of the prosthesis. In this type we may find an analogy to "bending cantilever instability" in cemented prostheses according to Gruen (9).

It is generally known, that stability at the bone-implant interface is the most important factor for good fixation of implants within the bone (10, 15, 16). We have distinguished primary and secondary fixation of the femoral cementless hip prosthesis at the metaphyseal and diaphyseal level. Primary fixation of the prosthesis, as a result of proper surgical preparation of the bone, was present only in 18 our cases (25%). Secondary fixation, as a result of the healing process at the bone-implant interface was present in all 52 remaining cases (75%). It seems to us that the type of fixation, primary or secondary, does not influence clinical results in the mid-term follow-up period.

Conclusions

1. We found differentiated and dynamic evolution of the radiological image if the femur, after implantation of cementless total hip prosthesis, in cases of good clinical outcome.
2. The analysis of the selected radiological parameters of the femur, after implantation of cementless smooth-surfaced total hip prosthesis, revealed 4 types of fixation: primary metaphyseal and diaphyseal, secondary metaphyseal and diaphyseal, primary metaphyseal and secondary diaphyseal, primary diaphyseal and secondary metaphyseal fixation.
3. The primary or secondary type of fixation does not seem to influence the clinical outcome in the mid-term follow-up period.

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STRESZCZENIE

Zanalizowano zmiany radiologiczne w kości udowej po wszczepieniu bezcementowej endoprotezy biodra typu Bichat III. Poddano 3-letniej ocenie 70 niepowikłanych chirurgicznie przypadków, analizując strefę przylegania endoprotezy do warstwy korowej kości, tzw. kontakt korowy, linię przejaśnienia i sklerotyzacji na granicy kość—proteza oraz grubość warstwy korowej i konsoli kostnej. Na podstawie obrazu radiologicznego wyróżniono 4 typy fiksacji protezy: 1) pierwotnie przynasadowo-nasadowy, 2) pierwotnie przynasadowy i wtórnie nasadowy, 3) wtórnie przynasadowy i nasadowy, 4) pierwotnie nasadowy i wtórnie przynasadowy. Wydaje się, że wyróżnione typy fiksacji endoprotezy pozostają bez wpływu na pooperacyjny wynik kliniczny 3-letniego okresu analizy wybranego materiału.