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Influence of Clinical and Radiological Variables on the Extent and Distribution of Periprosthetic Osteolysis in Total Hip Arthroplasty with a Hydroxyapatite-Coated Multiple-Hole Acetabular Component: A Magnetic Resonance Imaging Study

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ABSTRACT

Polyethylene wear-induced osteolysis constitutes the most severe long-term complication of total hip arthroplasties (THA). Our aim was to assess through MRI the severity and growth pattern of osteolysis, as well as the influence clinical-radiographic variables exert. We analyzed 75 THA with an average evolution time of 13.67 years. The implant was a titanium alloy, non-cemented, multiple-hole model with hydroxyapatite coating. Osteolysis was found with a peripheral pattern in 48 and a central pattern in 6; in 52 cases it was continuous, and in 4, isolated. Out of 118 screws, 20 exhibited lysis. There was a proportional correlation between osteolysis severity and wear rate with age, physical activity and acetabular abduction, as well as an association between said variables and peripheral and continuous patterns.

With the advancements in orthopedic surgery and the improvements in total hip arthroplasty design, instability and implant loosening issues have been overcome. Thus, friction component failures have now become the greatest problem. Developments in tribology and the refinement of friction torques have allowed for the extension of implant survival well over a decade. In this respect, polyethylene combined with metals or ceramics has exhibited an optimal behavior. Paradoxically, during these long periods of survival, polyethylene wear and wear-related osteolysis are still causes of failure in total hip arthroplasties in the long term [1–4]. This process starts as an inflammatory response against particles produced by the wear of the liner, and several factors condition the severity of the disease [2,5–7]. The therapeutic approach is complex because diagnosis is usually late, this being a "silent" process. Diagnosis is derived from the complications the disease may generate, especially aseptic loosening [8–11]. Due to the lack of specific symptoms until the disease reaches an advanced stage, conventional radiography (RX) may be the best instrument that allows us to pinpoint the disease. The low cost of this procedure, together with acceptable accuracy and specificity, makes radiography the first method of assessment. However, its scarce utility in the multiplanar study of the disease has furthered the use of three-dimensional techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI) [12,13]. CT is useful in determining the extent and volume of osteolysis during surgical planning [14,15], but MRI is the most sensitive non-invasive method for the detection of osteolysis, because it is more precise than CT at spotting bone loss and allows for the study of the disease not as a series of unrelated lytic lesions, but as a continuous granuloma formation, which is a constant in the extension of this pathology [16–20]. MRI also allows us to learn how osteolysis develops in terms of location and magnitude. Nowadays, it is known that osteolysis follows a continuous and peripheral pattern in uncemented THAs, and that whenever acetabular holes are present, lesions build up around them [21–23]. This pattern is influenced by how PE wear particles spread. Some authors, such as Schmalzried [24] and Anthony [25], have proposed that variations in hydrostatic pressure push wear particles through what has been defined as "effective joint space." This space originates mostly in a continuous fashion from the peripheral rims of the implant and, to a lesser extent, from the screw holes. Although factors related to greater wear and more osteolysis have been described [2,5–7,26,27], there are no MRI

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studies which may allow to establish a direct relationship between the different causal factors and the extent and pattern of lesions.

The aims of our study were:

1 To analyze the severity of osteolytic lesions, their spreading pattern and degree of continuity, assessing whether their progression matches the concept of "effective joint space."
2 To determine which clinical and radiographic factors have an impact on the magnitude and topography of the aforementioned osteolytic progression pattern, as well as the influence the type of implant used may exert.
3 To find out the repercussions of the presence of acetabular screw holes in the onset and development of periprosthetic osteolysis.

Materials and Methods

Our study was based on a sample of 75 consecutive cases of long-term evolution THAs implanted in a single hospital between 1992 and 1999 with an average evolution time of 13.67 years [6–18] (mean of 15). All cases featured primary surgery and the same model of uncemented arthroplasty was implanted (BihaPro, Biomet, UK), which consists of a multiple-hole hydroxyapatite (HA) coated porous acetabular component with three peripheral flaps for primary fixation, and an HA coated metaphysiary circumferential porous femoral stem with metaphysiary support, featuring a metal-PE friction torque and 28-mm chromium-cobalt head. The PE-acetabulum fixation systems used were the Hex-loc system in the case of the 18 THAs implanted before 1994, and the Ring-loc system in the other 57. The polyethylene employed was ultra-high-molecular-weight PE (UHMWPE), sterilized with gamma radiation. Only those cases with a valid clinical and radiographic follow-up were included. Patients who had undergone any sort of revision surgery before being enrolled in the study and who had no preoperative MRs were excluded. Those who did have MRs were included.

The series comprised 52 patients, 29 men and 23 women, and there were 23 bilateral cases. Average age at the time of surgery was 56.64 years (29–78, SD: 9.731). Patients included in the study signed an informed consent form and the guidelines set by the regional Ethics Committee were followed. The indication for surgery was primary coxarthrosis in 56 cases, hip dysplasia in 8, aseptic necrosis of the hip in 7, and other causes in 4. Surgical approach was anterior in 55 cases, lateral in 4, and posterior in 16. The implant was placed on the right side in 38 cases and on the left side in 37 cases. A total of 118 screws were inserted in 55 of the 75 acetabular components in the series (1 screw in 5 cases, 2 in 37 cases, and 3 in 13 cases).

All patients followed a clinical and radiographic follow-up protocol as part of the hospital follow-up procedure, which took place one, three, six and twelve months after surgery, and once a year afterwards. Furthermore, at the time of enrolment in the study and before performing the MR, a new assessment was carried out according to the parameters set in the aforementioned protocol. Since the entity of the protocol is remarkable, we proceed to detail the variables we used in this study: the etiology of the arthrosis and convenience of surgery, the surgical approach, whether the implant was unilateral or bilateral, the side undergoing surgery, age, gender, height, weight and body mass index (BMI) of the patient. A full medical history and a physical examination allowed for the clinical and functional evaluation according to Merle D'Aubigé's scale as modified by Chamley [28]. This scale assigns a score between 0 and 6 to each of three variables (pain, gait and mobility) and classifies the clinical outcomes of surgery according to the increase in the resulting overall score obtained by adding the scores of the three variables. Physical activity was measured by an additional 6-degree score: bed, sedentary, semi-sedentary, light, moderate and high. For the radiographic study at least two simple projections were obtained, including an antero-posterior radiograph of the pelvis centered on the pubic symphysis. The radiographs were used to analyze a series of variables we considered could be related to osteolysis: height of the greater trochanter with respect to the center of the femoral head, acetabular abduction (defined as the angle formed by the axis of the largest diameter of the acetabular cup and the bi-ischial line), extent of bone covered by the HA coating of the stem and the acetabular cup (defined as the distance in mm from the end of the HA coating and the last spot where HA is in contact with the bone), eccentricity of the prosthetic head, and polyethylene wear rate. PE wear rate was measured only in the last digitized set of radiographs for each case, comparing them with the immediate postoperative ones using the ROMAN software version 1.7 [29–31]. This program calculates wear based on the penetration of the prosthetic head in relation to the center of the acetabular cup. Whenever both centers coincide in the post-operative radiograph, the software performs a simple analysis, measuring the distance from the center of the head to the center of the acetabular cup in the last radiograph. If centers do not match in the post-operative radiograph, the software calculates penetration by means of a paired analysis, such as the relative displacement of both centers over time. Radiographic suspicion of osteolysis was also taken into account, based on the detection of radiolucencies around the implant or osseous cysts in the acetabular Lee-Charnley zones and in the femoral Gruen zones [32].

Finally, 75 MRs were also performed, one for each THA, using a Philips Achieva 1.5 T (Koninklijke Philips Electronics N.V., Amsterdam, The Netherlands) device in all cases. In order to achieve a good quality and minimize artifact interferences, we followed the guidelines described by Potter [18,19]. The study technique described below was performed according to those recommendations. At least three sequences were carried out: axial T1-weighted fast spin-echo (FSE), coronal T1-weighted FSE, and coronal T2-weighted FSE at 3-mm slice thickness in all cases. Whenever a more precise evaluation of the lysis areas in the acetabular region was required, an additional sagittal T1-weighted FSE sequence at 3-mm slice thickness was performed in order to add a supplementary slice plane which may help to further understand the three-dimensional nature of the process. If the axial T2 FSE sequence revealed any cystic changes in the skeleton or the regional soft tissue, a final coronal T2-weighted FSE sequence was performed to obtain a more precise definition of such changes. When choosing the acquisition parameters, we gave preference to spatial resolution (a 3-mm slice thickness in all cases and 384×317 imaging acquisition matrices). If a patient's build required a higher number of slices than usual the number of acquisitions (NSA) was reduced from 6 to 4, thus shortening the study period significantly. The same approach was used whenever a patient did not tolerate the examination well. To sum up, the average parameters for a T1-weighted sequence were: TR = 550, TE = 16, FSE Turbo = 3, NSA = 6; acquisition matrix = 384×317, which allows for a 512×512 reconstruction matrix. Parameters for T2: TR = 5700, Te = 140, FSE = 19, NSA = 4, matrix = 384×319.

Presence of osteolysis, its extent, the location of the lytic lesions and the growth pattern (central or peripheral and continuous or isolated) were analyzed in each MR. With that aim, a specific protocol defined before the study was followed. We thus considered two types of lesion:

(1) An osteolytic lesion defined as a zone of intermediate signal surrounded by a hypointense area which replaces the hyperintense signal of bone and which communicates with the joint, or
(2) A granulomatous lesion, defined as an area with the same signal features than an osteolytic lesion but without bone turnover.

In order to assess the location of the lesions, the pelvis was divided into five zones: the supra-acetabular ilium, the ilio-pubic branch, the pubis, the ischium, and the retro-acetabular ischium (Fig. 1). The femur was divided into the well-known Gruen zones Gruen [32]. The extent of osteolysis was determined according to the number of affected zones; the disease would be considered as "advanced" whenever 4 or more zones were compromised.