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Very low wear rate measured in a hip endoprosthesis removed after 38 years

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Abstract A Marino Zuco hip prosthesis implanted in 1963 in a 13-year-old girl with congenital hip dislocation was revised in 2001 for aseptic loosening. At the time of revision surgery, no granulomatous tissue reaction due to massive wear was observed. Considering the notable 38-year survival of this implant, we measured linear and volumetric wear of the acrylic ball head using a digital method to reconstruct the original spherical surface. Linear wear was 0.817 mm (21.5 μm/year) and volumetric wear was 28.937 mm^3/year. These low wear rates are attributed to the patient's limited range of motion during the implant's life time. Low prosthetic use may have contributed to the long implant survival time.

Key words Hemiarthroplasty • Mould arthroplasty • Wear rate • Polymethylmethacrylate ball head

Introduction

The development of total hip prostheses began in 1923 with the mould arthroplasty introduced by Smith Petersen [1]. Since then, many changes in materials and design have occurred because of implant failures. In 1946, the Judet brothers implanted a hip prosthesis made entirely of polymethylmethacrylate [2, 3]. Hemiarthroplasty was first proposed by Thompson in 1952 with an intramedullary hip prosthesis made of vitallium [4]. In 1956, after three years of experiments, two models of hip prosthesis were proposed by Marino Zuco in Italy [5]. The first model was made of metallic or acrylic-metal cup fixed on a femoral neck with two small metallic plates and screws. The second model, like the Thompson one, had a polymethylmethacrylate ball head and used extramedullary fixation with a small plate and screw (Fig. 1).

In 1963, we used this second hip prosthesis model to treat a 13-year-old girl with congenital hip dislocation. We revised this implant 38 years later, and found no signs of host tissue reaction around the acrylic ball head (Fig. 2).

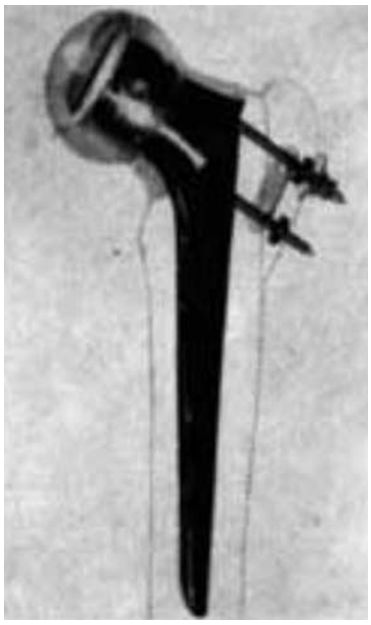

Fig. 1 The second hip prosthesis model proposed by Marino Zuco in 1956

Fig. 2 Implant retrieved from patient 38 years after implantation

Presently, there are only a few reports on implant survival beyond 30 years [6–8]. Therefore, in this study, we analysed the linear and volumetric wear of the acrylic ball head after 38 years with hemiarthroplasty in place.

Patient and methods

Case report

In 1962, a 12-year-old girl underwent anterior enervation, adductors tenotomy and open reduction followed by cast immobilisation for one month because of a congenital left hip dislocation. At time of cast removal, range of motion (ROM) was limited: flexion excursion was 20°; hip external rotation was 5° and internal rotation was 5°; abduction was 30° and adduction was 25°.

One year later, clinical evaluation revealed worsening of ROM and persistent pain. Therefore, at the age of 13 years, in 1963, the patient was implanted with the second model of Marino Zuco's endoprosthesis. After the operation, a plaster cast was applied for one month. ROM of the left hip at the end of the treatment was moderately limited: flexion excursion was 50°; hip external rotation was 10° and internal rotation was 10°; abduction was 30° and adduction was 20°. The activity level of the patient during the 38 years with the hemiarthroplasty in place was poor as indicated by ROM.

In January 2001, at the age of 51 years, the patient was admitted to the Orthopaedics Department of Catholic University, Rome, for left hip pain. ROM of the hip was extremely limited: flexion excursion was 20°; hip external rotation was 5° and internal rotation was 5°; abduction was 20° and adduction was 10°. The Harris hip score was 54. The left leg was 4 cm shorter than the right one. Radiographs showed the presence of a cementless endoprosthesis, extramedullary fixed with plate and screw. The acetabular space seemed intact. Radiographs also showed grade 3 Broker calcifications, explaining the limited ROM (Fig. 3).

Fig. 3 Preoperative radiograph showing the absence of radiolucent signs in the acetabulum

The patient underwent a total hip revision with a Wright Cremascoli Ortho Profemur stem and a Smith Nephew reflection socket (Fig. 4). At the time of surgical revision, no granulomatous reaction was observed. Intense physical therapy followed surgery. Partial weight bearing with external crutches was allowed 3 days after operation. Full weight bearing was allowed 2 months postoperatively. Postoperative time was uneventful and pain-free.

Fig. 4 Postoperative radiograph of a patient undergoing a difficult total hip revision

At the 3-year follow-up, the patient walks without pain and has the left leg 1.5 cm shorter than the right one. At this time, clinical evaluation showed good ROM (flexion excursion, 70°; hip external rotation, 10°; hip internal rotation, 10°; abduction, 30°, adduction, 20°). A Harris hip score of 81 revealed considerable improvement in quality of life.

Analysis of implant wear

The methods for wear analysis have been reported previously [9] and are here described in brief.

The acrylic ball head was observed through stereomicroscopy for qualitative analysis of wear. A computerized, numerical-controlled three-dimensional (3D) coordinate measurement system (DEA-BROWNE&SHARPE SWIFT model) connected with Surfer NT software for reverse-engineering (Mirai, Bologna, Italy) was used. The digitalized surface images were imported into a 3D CAD system (EDS Unigraphics) using IGES format to permit quantitative analysis of linear and volumetric wear. The overall precision of this method is estimated to be $1x10^{-2}$ mm.

The original dimension of the acrylic ball head was obtained using an experimental method with three kinds of measurements. We measured 25 points of the superior hemisphere according to ISO 7206–2 [10], with a 3D measurement system establishing the centre and ray of the sphere. In the second method, using the same system, we manually selected points under the equator, where we expected minimum wear. The third method employed a CAD system to study all digitalized surfaces of the acrylic ball head. At the end of the analysis, all measurements were compared. We used a polar coordinate system on the sphere, with the Z axis going through the pole, the X axis for the anteroposterior plan and the Y axis for the medial-lateral plane.

Linear wear was measured considering 6 meridians on which 13 points were analysed for each meridian. For each meridian, we made, 1 polar diagram and 2 bidimensional diagrams (Fig. 5).

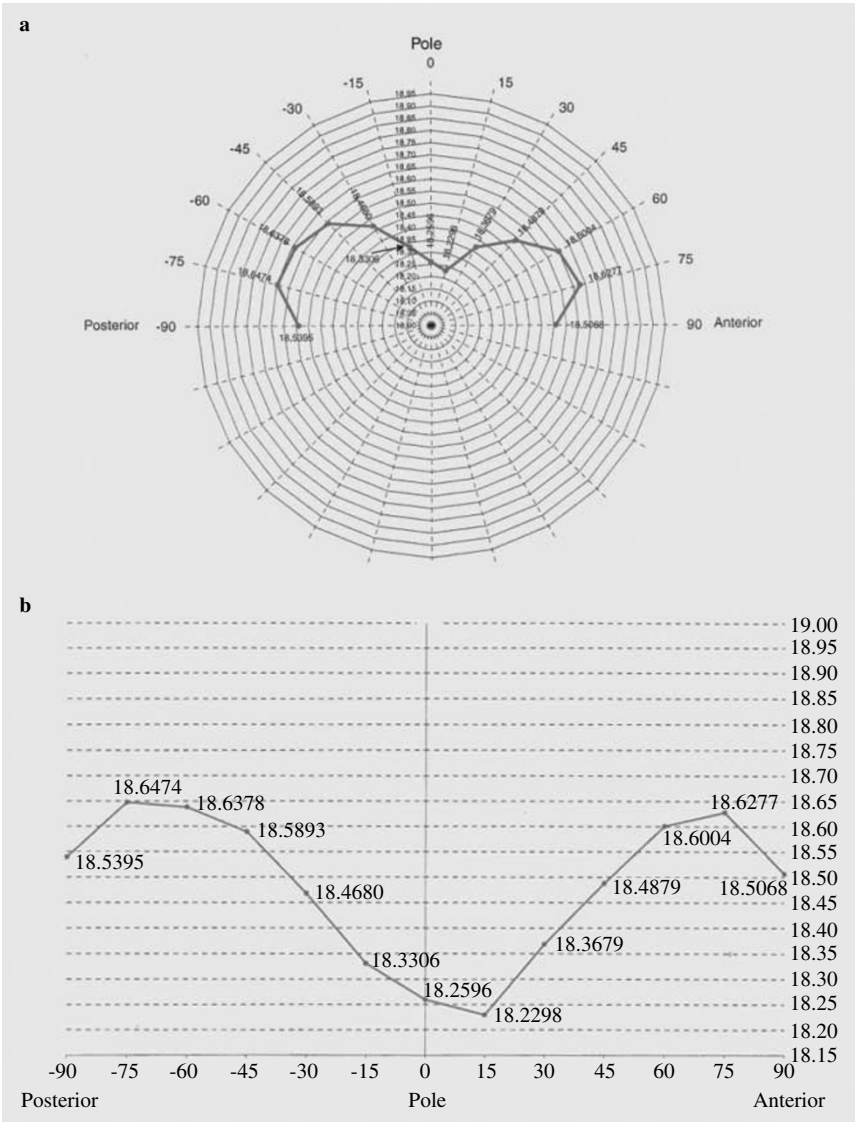

Fig. 5 Polar (**a**) and bidimensional (**b**) diagrams made to measure linear wear, considering 13 points on 6 meridians

Volumetric wear was measured as the difference between the volume of an ideal sphere of 38 mm diameter and that of the retrieved head, using Unigraphics system.

Periprosthetic membrane tissue collected at the time of surgery was fixed in 10% neutral buffered formalin, decalcified in ethylenediaminetetraacetic acid (EDTA), dehydrated, embedded in paraffin, sectioned and stained with haematoxylin-eosin and Gomori-Halmi stains.

Results

Stereomicroscopy showed some abrasions on the acrylic ball head. New bone was observed at the neck-stem junction. Stereomicroscopy confirmed the absence of macroscopic wear. The stainless steel stem showed many scratches on the surface due to bone abrasion.

Through 3 measurements of the acrylic ball head, we estimated that the original diameter was 38.00 mm. We measured linear wear as the difference between the radius of an ideal sphere of 19 mm and the lowest diameter (18.1830 mm) measured at 30° inclination with respect to the Z plane. Using these parameters, linear wear was 0.817 mm. Considering 38 years of implantation, wear was 0.0215 mm/year, or 21.5 μm/year. Volumetric wear was calculated as the difference in volume between that of an ideal sphere of 38 mm diameter and that of the retrieved head. The difference was 1099.6091 mm^3 or 28.937 mm^3/year.

Histologic section of membrane showed fibrous tissue. We observed no histological signs of granulomatous reaction nor presence of foreign body cells.

Discussion

In this study, linear and volumetric wear was measured on a Marino Zuco endoprosthesis, removed after 38 years without radiographic signs of loosening. ROM was limited before implantation of the endoprosthesis due to a previous surgery and the subsequent immobilization. We postulate that the discrepancy in leg length (4 cm) also influenced ROM. This ROM limitation may explain the low linear and volumetric wear measured. In fact, the acrylic ball head maintained its rounded surfaces. In fact, the crylic ball head maintained its rounded surfaces although it has been found that polymers which perform satisfactorily as components with concave bearing surfaces perform less well when the bearing surface is convex [10]. Notwithstanding the low wear rate of the head, the most involved areas were around the pole, towards the front and rear, in an angle between 30° and -30°; the less involved areas were around medial and lateral parts. These results demonstrate that the most important movement was from the anterior to the posterior parts, during flexion and extension of the hip.

Very limited ROM surely influenced the low debris production. Schmalzried et al. [11] reported that wear is a function of prosthetic use and not of implantation time. We conclude that in our case the very limited ROM, not inducing the production of wear particles, did not activate the cascade of foreign body giant cells, leading to osteolysis and implant loosening. Therefore, low linear and volumetric wear rates and biological reaction without giant cells may be considered key factors in the long life of the analysed implant.

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