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ORIGINAL PAPER

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Osteodensitometry after total hip replacement with uncemented taper-design stem

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Abstract We followed 24 patients (26 hips) with uncemented total hip replacement for a minimum of 3 years. Patient mean age was 52 (40–69) years. The aim was to evaluate femoral periprosthetic bone mineral density (BMD) using quantitative computed tomography osteodensitometry. At 3-years' follow-up, 25 hips were clinically rated good or excellent. The mean Harris hip score rose from 58 (49–68) pre-operatively to 94 (81–98) at the last follow-up. All hips were radiologically stable. Mean decrease of the overall BMD in the femoral metaphysis was 14.3%, and mean decrease of cortical BMD was 17.3%. In the diaphysis, mean decrease of overall BMD was 5.5% and mean decrease of cortical BMD was 4.5%. Observed loss was markedly lower than in comparable series with uncemented stems.

Résumé Nous avons suivi 24 malades (26 hanches) pendant un minimum de trois ans après arthroplastie par prothèse totale non cimentée. L'âge moyen des malades était de 52 ans (40–69) . Le but était d'évaluer les densités minérales osseuses (DMO) périprothétiques fémorales en utilisant la tomodensitométrie qualitative. Àprés 3 années, 25 hanches ont été estimées cliniquement bonnes ou excellentes. Le Score de Harris moyen a été élevé de 58 (49–68) en préopératoire à 94 (81–98) au dernier suivi. Toutes les hanches étaient radiologiquement stables. La baisse moyenne de la DMO totale dans la métaphyse fémorale était de 14,3%, et la baisse moyenne de la DMO corticale était de 17,3%. Dans la diaphyse la baisse moyenne de la DMO totale était de 5,5%, et la baisse moyenne de la DMO corticale était de 4,5%. La perte observée était notablement inférieure à celle notée dans des séries comparables de tiges non cimentées.

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Introduction

Proximal bone remodelling after insertion of a femoral component depends on the mechanical properties of the bone as well as implant geometry and stiffness [1, 4, 7, 20]. There is currently much interest in tracking bone changes using osteodensitometry. Quantitative computed tomography (qCT) osteodensitometry is a radiological method for three-dimensional investigation of the bone structure with high validity and high resolution [15, 22]. This method has been used with dedicated artefact-reduction software to measure changes of peri-prosthetic bone mineral density (BMD) in total hip replacement (THR) [20, 23].

The aim of this prospective study was to assess femoral BMD changes in patients operated on using a taper-design un-cemented stem. We anticipated limited adaptation phenomena based on the assumption that taper stems provide a self-locking fixation in the proximal portion of the femur and have a low modulus of elasticity [11, 24].

Material and method

Twenty-six consecutive hips (24 patients) with osteoarthritis received an un-cemented THR (Cerafit Triradius-M press-fit cup and Cerafit Multicone stem, Ceraver Osteal, Paris, France) and were prospectively followed-up for a minimum of 3 years. Inclusion criteria were patient age less than 70 years, elevated functional demand and bone quality type A or B [4]. The Multicone femoral component is a collarless, three-dimensionally tapered wedge made of titanium alloy ($TiAl_6V_4$). The whole surface with the exclusion of the neck is grit blasted. An alumina-alumina pairing with a femoral head diameter of 32 mm was used in all hips.

Mean patient age at index operation was 52 (40–69) years. There were ten men and 14 women. All operations were performed or supervised by a single surgeon using a direct lateral approach. Partial weight bearing was started at day 2 after surgery and continued until the sixth post-operative week. Patients were clinically assessed using the Harris hip score [12]. Femoral and acetabular radiological evaluation was performed using published criteria [2, 8, 10, 13].

Osteodensitometry with qCT (Somatom Plus 4, Siemens, Erlangen, Germany) was performed 10 (5–18) days, 1 year and 3 years after the index operation. Informed consent was obtained from all patients. Scan slide thickness was 2 mm, the table feed (distance between two scans) was 10 mm. The legs were positioned in a cage at approximately 5° external rotation. The scan axis was adjusted vertical to the prosthesis axis. A phantom containing a circular sample with defined hydroxylapatite (HA) concentration (800 mg/ml) was scanned at the end of each CT examination. This was used for calibration and conversion of Hounsfield units into HA equivalents. An extended CT scale was used for image reconstruction and exposure of the prosthesis-bone interface [15, 16]. Overall (cortical and cancellous) BMD (milligrams per millilitre) and cortical BMD were determined separately using dedicated software [22].

Results

Clinical and radiological 3-year follow-up was obtained in all 26 hips. No hip required revision surgery. The mean pre-operative Harris hip score was 58 (49–69) points and was 94 (81–98) points at the last follow-up. Twenty-five hips were clinically rated good or excellent. One patient had moderate post-operative thigh pain, which disappeared 3 months after surgery.

All stems presented radiological stable fixation with bone in-growth. Post-operative subsidence (rated less than 2 mm) was seen in one stem. Osteolytic lesions were not observed. In seven hips, radiolucent lines with a non-progressive sclerotic reaction at the bone-implant interface were found in Gruen zones 1 and 8. A slight cortical hypertrophy was seen in two hips. Eleven hips developed radiographic appearance of bone apposition at the stem tip, in nine as a partial and in two as a complete pedestal. Two hips showed Brooker-I heterotopic ossifications.

The uncemented acetabular components were all considered radiologically stable with bone ingrowth. Non-progressive radiolucencies with peri-prosthetic sclerosis in DeLee-Charnley zone 1 were found in two hips and in zone 3 in one hip. There were no radiological signs of pairing wear.

Osteodensitometry was performed in 20 patients (20 hips) using qCT. In the proximal femur, mean decrease of overall BMD at 3 years' follow-up was 14.3% and mean decrease of cortical BMD 17.3% (Fig. 1). In the diaphyseal femoral portion, mean decrease in overall BMD was 5.5% and mean decrease of cortical BMD was 4.5%. Only slight changes of BMD were observed at the level of the tip of the stem (scan 10 to –20) (Table 1).

Decrease in peri-prosthetic BMD occurred during the first year. Decrease of cancellous BMD was markedly less pronounced than decrease of cortical BMD. Interestingly, an almost-complete return to baseline values was detected in the distal half of the femur (scan 10–60) at the 3-year follow-up. In the proximal half, a partial return to baseline values was observed at the 3-year follow-up (scan 110–70). In contrast, a progressive loss of overall and cortical bone BMD was seen in the most proximal portion of the scanned femora at the level of the neck resection (scan 120). The slight increase of BMD observed at the level of the tip of the stem (scan 0) at the 3-year follow-up was probably caused by pedestal formation.

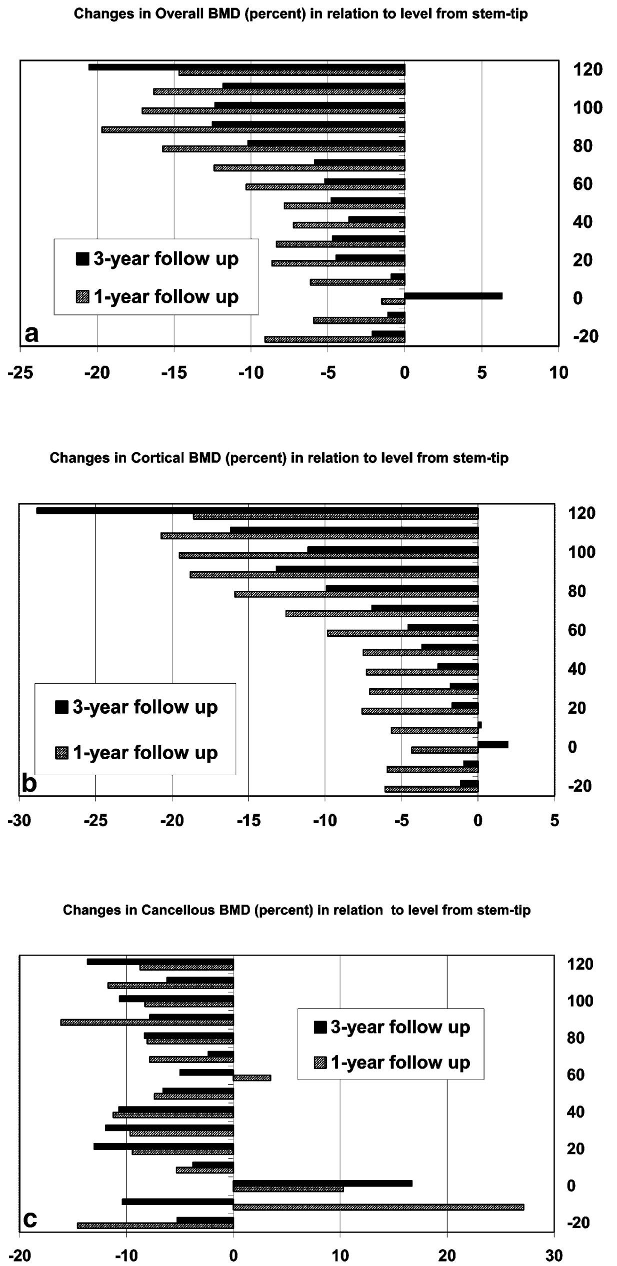

Fig. 1A–C Overall (**A**), cortical (**B**) and cancellous (**C**) bone mineral density (BMD) of the proximal femur 1 year and 3 years after total hip replacement (THR). Changes in comparison with the baseline values (post-operative) are depicted in percent. The marked loss of peri-prosthetic bone BMD detected at the first follow-up was partially or even completely recovered at the 3-year follow-up, with the exception of the most proximal scan (position 120)

Table 1 Overall, cortical and cancellous bone mineral density (BMD) (mg/ml) at the 1-year and 3-year follow-up. Baseline values are post-operative. Values are mean (standard deviation). Level 120 is the most proximal CT-scan. Level −20 is the CT-scan 20 mm below the tip of the stem

Level	Post-operation			1 year			3 year		
	Overall	Cortical	Cancellous	Overall	Cortical	Cancellous	Overall	Cortical	Cancellous
120	609(84)	809(88)	507(88)	519(129)	659(127)	462(121)	484(90)	576(62)	438(111)
110	624(102)	884(95)	481(113)	522(117)	701(129)	425(107)	551(109)	741(90)	451(115)
100	674(119)	925(78)	512(139)	559(187)	744(119)	470(258)	591(146)	822(176)	457(130)
90	782(157)	989(88)	605(194)	628(147)	803(175)	508(136)	685(167)	859(138)	558(194)
80	936(164)	1090(84)	757(232)	789(202)	917(113)	696(339)	841(154)	982(114)	694(191)
70	1087(126)	1192(62)	918(240)	952(142)	1042(107)	847(221)	1023(142)	1109(107)	897(209)
60	1179(98)	1229(65)	1079(251)	1057(127)	1108(94)	1117(620)	1117(130)	1173(99)	1025(233)
50	1212(88)	1247(62)	1144(272)	1117(129)	1154(103)	1060(241)	1154(130)	1202(88)	1069(256)
40	1201(74)	1252(60)	1150(388)	1114(120)	1160(98)	1021(221)	1157(112)	1219(78)	1027(266)
30	1200(87)	1256(59)	1048(250)	1100(116)	1167(91)	947(196)	1144(109)	1233(79)	922(212)
20	1194(88)	1263(58)	998(252)	1091(117)	1167(115)	903(188)	1140(106)	1241(79)	868(191)
10	1178(83)	1266(59)	902(195)	1106(112)	1194(111)	854(178)	1168(100)	1268(78)	868(168)
0	1115(117	1261(70)	698(249)	1098(137)	1207(121)	770(275)	1185(108)	1286(86)	814(213)
−10	949(113)	1241(82)	162(127)	893(140)	1167(125)	205(143)	938(95)	1229(84)	145(107)
−20	943(120)	1248(84)	125(68)	858(140)	1172(123)	107(84)	923(112)	1234(81)	118(89)

Discussion

Bone resorption in the proximal femur after un-cemented THR seems to result from stress shielding due to stiffness of the implant and the firm distal fixation by bone ingrowth. It is uncertain whether bone resorption reduces implant longevity , but a strong relationship has been found between thigh pain and load transfer to the stem tip [1, 6]. Moreover, loss of proximal bone support might increase the risk of peri-prosthetic or implant fracture [17]. Femoral components with taper design have been used to prevent proximal femur stress shielding, but little is known about their efficacy to reduce bone resorption. Zerahn et al. [26] found a BMD decrease of 15.7% in Gruen zone 1 and 28% in zone 7 using dual-energy X-ray absorptiometry (DEXA) in 15 hips at a mean of 21.7 months after THR with Cementless System (CLS) stems. Similarly, Gibbons et al. [9] found a BMD decrease of 13.5% in Gruen zone 1 and 21.5% in zone 7 using DEXA in 22 hips 52 months after THR with the same brand of stem. Rosenthall et al. [21] investigated BMD changes with DEXA in 25 hips operated on using the Multilock tapered stem at a mean follow-up of 4 years. BMD loss was 25.4% in Gruen zone 1 and 22.1% in zone 7. Interestingly, this BMD loss was in 40 hips operated on with the same stem, but with the proximal surface coated with hydroxylapatite, it was only 15.9 in Gruen zone 1 and 5.6% in zone 7.

In the present study, the mean decrease of the overall BMD in the femoral metaphysis was 14.3% at the 3-year follow-up, and mean decrease of cortical BMD was 17.3%. In a previous study, we reported an overall BMD loss of 14.2% and a cortical BMD loss of 15.5% in the metaphyseal portion of the femur in 15 hips at the 3-year follow-up after THR using the same tapered stem, but with hydroxylapatite coated surface [23]. In contrast, up to 38% decrease of proximal femoral BMD has been reported in the literature [1, 7, 14, 16].

The present study showed that loss of femoral BMD in THR is not necessarily progressive, and a full or at least partial restoration of baseline values around the implant may occur within the first 3 years after operation with tapered stems. A longer follow-up is required to substantiate this encouraging finding, which seems to confirm the rationale of stems with tapered design. Interestingly, the mean loss of cortical BMD was markedly higher compared with the mean loss of cancellous BMD. This finding indicates that peri-prosthetic bone remodelling affects primarily the cortex, resulting in resorption and atrophy. On the other side, intra-medullary load transfer along the implant shelters cancellous bone from major changes, or even stimulates new bone apposition and hypertrophy. This phenomenon has been as well observed in a canine model study and in retrieved human femurs [5, 25].

The method used in the present study for quantitative evaluation of periprosthetic bone remodelling allows an accurate analysis of bone structures with a consistent reduction of soft tissue and metal artefacts [19]. In the present study, patients had a mean age of 52 years, a high level of activity and good bone quality of the proximal femur. Although uncemented stems can be used effectively in ageing patients, the mere act of impacting the prosthesis carries the risk of producing a longitudinal fracture and should be avoided.

In conclusion, the clinical and radiological outcome at an average of 3 years using Multicone femoral components is comparable to those achieved with contemporary tapered design stems [3, 11, 18, 24]. BMD decrease observed 3 years after operation was considerably less pronounced than that reported in the literature [7, 9, 21, 26]. We continue to use taper-design stems for patients under the age of 75 years with good bone stock and high functional demand.

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