ORIGINAL ARTICLE

Long-term results of the ABG-1 hydroxyapatite coated total hip arthroplasty: Analysis of 111 cases with a minimum follow-up of 10 years

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Accepted: 5 October 2009

KEYWORDS
Uncemented total hip arthroplasty; Hydroxyapatite coating; Osteolysis

Summary
Introduction: Medium-term studies of ABG-1™ cementless total hip arthroplasty have shown favorable functional results with excellent femoral component fixation but an abnormally high rate of periacetabular component osteolysis, which may require early revision.
Hypothesis: The periacetabular osteolysis rate increases with time with the ABG-1™ implant, leading to a high revision rate.
Objective: The objective of this study was to test this hypothesis with a minimum follow-up of 10 years and evaluate the progression of periacetabular osteolysis and its consequences on implant fixation.
Material and methods: A continuous series of 111 ABG-1™ cementless prostheses implanted by a single operator with a theoretical minimum follow-up of 10 years. Seventy-five implants were analyzed with a mean follow-up of 13 years. All the prostheses had been implanted via a posterolateral approach and consisted of a 28 mm cup matching a head in zirconia and an antidislocation rim design high-density polyethylene insert.
Results: Twelve cups were revised because of progressive retroacetabular osteolysis. The revisions were performed systematically although there was no pain or gross cup loosening. The revisions included resection of the granuloma, cavity filling with morselized bone grafts, and implantation of new uncemented ABG-2™ cups in eight cases or cemented cups associated with a support ring in the four other cases. Thirty-two (48.5%) of the cups still in place at the end of the follow-up evaluation presented moderate and asymptomatic radiographic osteolysis, inciting close subsequent observation. No predictive factor of osteolysis onset was identified (age, body mass index, polyethylene wear, or cup orientation). None of the femoral stems was changed because of osteolysis: the only two femoral revisions resulted from periprosthetic fracture and one case of bipolar loosening.

DOI of original article:10.1016/j.rcot.2009.09.026.
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Introduction

The cementless first-generation anatomic Benoist Girard total hip prosthesis (ABG-1™) was introduced and widely implanted in Europe beginning in 1989. Several series reported good short- and medium-term results with these implants [1—10], but to our knowledge, no study has reported results with a minimum follow-up of 10 years. William Harris [11] suggested that the main factor in cementless implant failure was osteolysis. The ABG-1™ prosthesis was unfortunately no exception in the above-mentioned series [1—10]: they present a high rate of cup failure but a long-lasting fixation and better survival for the stems. The objective of this study was to determine whether the frequency of osteolysis observed with the ABG-1™ implants worsened with time and whether they were responsible for an increase in the number of revisions and loosening beyond 10 years. To test this hypothesis, we conducted a clinical and radiographic analysis of a continuous series of ABG-1™ prostheses implanted by the same operator, with a minimum follow-up of 10 years.

Material and methods

Patients

The continuous series included 111 total hip arthroplasties (THAs) with implantation of the ABG-1™ system, performed by a single senior operator (G.A.), in 101 patients (ten bilateral implantations). A single implant model was retained for all patients during this period from January 1990 to December 1994. A total of 53 women (57 THA) and 48 men (54 THA) were treated. The inclusion criteria in this retrospective study were a minimum radiographic and clinical follow-up longer than 10 years.

At revision, 19 patients (21 THAs) had died of causes independent of the arthroplasty before this follow-up time, 14 patients (14 THAs) had been lost to follow-up, and one patient refused to be seen (implant still in place). Six patients with their prosthesis still in place were contacted by telephone because of poor general health. The clinical and radiographic review was carried out by an observer who had not participated in the interventions (B.R.) for 69 THAs and by telephone questionnaire for six THAs. This series studied 75 THAs, divided into 46 THA right and 29 left THAs. The mean age of the patients at implantation was 63.1 years (range, 33—83); their body mass index (BMI) was 25.3 ± 3.4 kg/m² (range, 17.3—32.8).

These arthroplasties were performed in 38 cases for primary coxarthrosis, in three cases for rapid destructive coxarthrosis, in six cases for rheumatoid arthritis, in nine cases for posttraumatic osteoarthritis, in two cases for congenital hip dislocation sequela, and in one case for consersion of a hip fusion.

Implants

The ABG-1™ acetabular component is designed as a hemisphere in a titanium alloy with 12 holes for increased primary stability by added screws or spikes. Its hydroxyapatite (HA) coating provides medium- and long-term secondary stability to the implant through its osteointegration properties. It was implanted in 72 cases. In three cases, a cementless threaded cup (Titan™, Depuy-Landanger, UK) was put in place. However, to present a homogenous series of ABG-1™ acetabular implants, these three threaded cups were removed from the clinical and radiographic analyses. All the polyethylene (PE) inserts of the ABG-1™ cup used were made in high-density PE with an antisubluxation rim impacting in this metal-backed cup with a two-”“olive” blocking system.

The ABG-1™ femoral component was also made of titanium alloy coated with HA on its metaphyseal proximal third for secondary biological anchoring. Its anatomic design characterized by anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterior curvature straightened on its anteroposterosis with grafts combined with acetabular cup revision. This procedure remains simple as long as performed before the onset of massive bone destruction, confirming the proposed revisions in this series were judicious. This study also confirms the excellent long-term fixation of the ABG-1™ femoral stems derived from the osteointegration and proximal seal around the hydroxyapatite coating.

Discussion, conclusion: This long-term study confirms the high frequency of retroacetabular osteolysis of ABG-1™ prostheses surpassing the osteolysis rate of other uncemented cups with a polyethylene insert. The absence of predictive criteria of osteolysis occurrence and the lack of symptoms warrants periodic follow-up of patients with ABG-1™ cups and, if necessary, early repair of bone stock loss with grafts combined with acetabular cup revision. This procedure remains simple as long as performed before the onset of massive bone destruction, confirming the proposed revisions in this series were judicious. This study also confirms the excellent long-term fixation of the ABG-1™ femoral stems derived from the osteointegration and proximal seal around the hydroxyapatite coating.

Level of evidence: Level IV: retrospective therapeutic study.
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the dorsal hip muscles. The ABG-1™ cementless acetabular implant was impacted after avivement of the acetabulum in subchondral bone; the cup orientation reproduced the orientation of the acetabulum. Two spikes or screws, in the superior polar position, were added systematically to increase primary stability. Before implanting the femoral component, the medullary canal was reamed to a dimension 1 mm greater than the stem caliber, followed by preparation with specific rasps progressively increasing in size, systematically beginning with the smallest (size 1) and pushing the rasp shoulder into the trochanteric fossa until perfect rotatory stability was achieved. Associated procedures were performed in eight cases: four acetabular shelf acetabuloplasties, two ablations of former fixation devices, and two releases of the hip adductor muscles. Antibiotic therapy was provided postoperatively for 48 h. Preventive measures against heterotopic ossifications were not taken systematically. Full weightbearing was allowed the day after surgery, supervised by a physical therapist.

**Evaluation method**

The clinical and radiographic review was carried out by an observer that did not participate in surgery (B.R.). Preoperative assessment and then at revision used of the Postel Merle d’Aubigné (PMA) score [12] and the Harris Hip Score [13] as well as the Charnley function classification [14]. The radiographic parameters were analyzed on the AP pelvic images with load and on AP and lateral images of the prosthetic hips taken preoperatively, at the 3rd month postoperative, and at the latest follow-up. The femoral morphology was studied using the classification provided by Noble et al. [15]. Femoral metaphyseal filling was studied on AP hip X-rays taken immediately after surgery and femoral implant centering was measured. On the latest follow-up images, acetabular inclination, heterotopic ossification according to Brooker et al. [16], periacetabular osteolysis according to De Lee and Charnley [17] and femoral osteolysis classified according to Gruen et al. [18], stress shielding, and cancellous densification were all studied. Stability and implant fixation were evaluated using the ARA score [19] and Engh et al. [20] parameters. PE insert wear was measured using the technique reported by Livermore et al. [21], which was also used to calculate annual linear wear (ALW) corresponding to the total linear ratio measured divided by the time to onset of this wear.

All the results are expressed in mean values ± standard deviation. The survival curve was determined using the Kaplan-Meier method [22] with a 95% confidence interval.

We defined failure as surgical revision of the prosthesis for any cause. For the statistical analyses, the Student t-test was used to compare the clinical and radiologic data. The significance threshold was set at 0.01.

**Results**

**Complications**

Three early complications occurred in three patients: (a) one deep hematogenous alphahemolytic *Streptococcus* infection successfully treated with surgical debridement, preservation of the implants in situ, and adapted antibiotic therapy for 3 months. (b) Obturator neuralgia was treated by neurolysis of the obturator nerve. Pain persisted despite clear early clinical improvement. (c) Finally, a Vancouver AL periprosthetic femoral fracture at the 3rd postoperative month in a 65-year-old patient was treated surgically with bone cerclage and preservation of the femoral implant in situ. Later progression was satisfactory with osteointegration of the stem after a stem subsidence of 6 mm further and stabilizing it. However, no intraoperative, sciotic neurapraxia, or postoperative hematoma complication was encountered.

Eight late complications occurred in seven patients. (a) Six patients experienced dislocations (8%) after a mean 31.5 months after implantation, all in the posterior direction. Orthopaedic treatment with no recurrence was achieved in three cases, and recurring instability in the three other cases required secondary treatment: an isolated change of the prosthetic head with no other procedure on the implants left in place in two cases, at the 15th and 18th postoperative month, and one cup change to reposition the implant in one case, at the 112th postoperative month. The severity of the wear, inclination, cup diameter, head/cup diameter ratio, and the number of interventions on the hip before the first implantation did not influence dislocation occurrence. (b) One acetabular periprosthetic fracture in a 77-year-old patient after a fall, 11 years after implantation. This was a transversal fracture with little displacement of the acetabulum and no cup destabilization, treated orthopaedically with no later complications. (c) One traumatic periprosthetic femoral Vancouver B2 fracture in an 82-year-old patient at 12.5 years, treated by changing the femoral component with osteosynthesis.

**Implant changes**

We report a total of 14 cup changes ABG-1™. (a) Twelve of them involved retroacetabular osteolysis. The patients presented no pain or implant migration. These revisions were made on five men and seven women, 58.1 ± 14.9 years of age (range, 33—76) at implantation, with a mean follow-up of 131 ± 35 months (range, 60—180). Cup inclination was a mean 45.1° ± 2.1° (range, 38—52) and the wear rate was 0.21 ± 0.05 mm/year (range, 0.12—0.36). Second-generation cementless ABG-2™ cups were implanted (eight cases) and support rings with a cemented PE cup (four cases). (b) One case presented recurring instability (explained above) requiring cup repositioning at the 112th month after surgery. (c) The last case involved aseptic loosening with cup migration, making this a bipolar implant failure, with onset 40 months after conversion of a hip fusion in a young (43 years), highly active patient. In this revision, a new ABG-1™ acetabular prosthesis was implanted.

Two femoral components had to be changed, in one case for a Vancouver B2 periprosthetic femoral fracture (see above), and for the bipolar aseptic loosening occurring after the conversion of the fusion explained above. The femoral stem was replaced by a cemented reconstruction stem.
Clinical results

Of the 75 hips included with a minimum follow-up of 10 years and a mean follow-up of 13 ± 2 years (range, 10–17), the mean PMA score [12] rose from a preoperative mean of 11.8 ± 2.3 to 16.3 ± 1.7 at the last follow-up (p < 0.01) and the Harris score [13] progressed from 56.7 ± 12.4 to 87.3 ± 10.7 (p < 0.001). The specific parameters of these scores are detailed in Table 1. Pain showed the most significant improvement. No thigh pain was reported.

From a functional point of view, the patients’ capacities changed, with an increase in the number of joint involved according to Charnley [14], as shown by the significant differences in distribution between the preoperative and last follow-up state (Table 2).

Radiological results

Acetabular implants

Of the 69 complete radiological files studied, with the exception of the three Titan™ cups, 66 ABG-1™ cups and 69 femoral components were implanted. At revision, the mean cup inclination was 45.5 ± 6° (range, 28°–60°). Heterotopic ossifications were found in 30 cases (43.4%), divided according to Brooker et al. [16] into type 1, 20 cases; type 2, three cases; and type 3, seven cases.

All the cups presented signs of radiographic osteointegration. One cup presented an equatorial radiolucent line, less than 2 mm, in De Lee and Charnley [17] zones 1 and 3. Thirty-two cups (48.5%) presented retroacetabular osteolysis. For these implants, the mean inclination was 44.8 ± 5° (range, 28°–60°), the mean patient age at implantation was 63.4 ± 7.9 years (range, 34–82), there were 14 women and 18 men with a mean BMI of 25.6 ± 2.1 kg/m² (range, 22–32), and the mean PE wear measured was 0.17 mm/year ± 0.06 (range, 0.07–0.44). These parameters did not differ from the rest of the population studied and their statistical analysis did not allow us to correlate them with the onset of osteolysis. Study of the De Lee and Charnley zones showed osteolysis in 16 cases (24.2%) in zone 1, in 22 cases (33.3%) in zone 2, and in four cases (6.1%) in zone 3. All the other implants were considered stable according to Engh et al. [20]. The mean annual PE wear in the series was 0.16 mm/year ± 0.07 (range, 0.05–0.44). In 19 cases (28.8%), it was considered substantial (>0.2 mm/year).

Femoral implants

The preoperative morphological study of the implanted femurs found a normal femoral canal flare in 79.7% of cases and a cylindrical canal in 20.3%, according to Noble et al. [15]. Appropriate metaphyseal sizing of the stems was found in 72.4% of the cases, with the implant filling the proximal femur metaphysis between 80 and 90%. Oversizing (metaphyseal filling < 80%) was reported in 13.8% of the cases and oversizing (metaphyseal filling > 90%) in 13.8% of the cases. In three cases (4.4%), a varus position greater than or equal to 5° was noted. No valgus position greater than or equal to 5° was observed.

Our study demonstrated no correlation between cortical flare, implant position, and implant size. These three parameters were not influenced by age, sex, BMI, and the patients’ Charnley score before implantation. Sixty-five stems (95.6%) presented cancellous densification, creating spotwelds oriented diagonally from top to bottom between the implants and the femoral cortices, distributed, according to Gruen et al. [18], in zones 2 for 64 stems (92.7%), in zone 6 for 65 stems (94.2%), in zones 3 for 23 stems (33.3%), and in zone 5 for 22 stems (31.9%). Twelve stems (17.4%) presented condensations perpendicular to the stem support, in zone 1b. Forty-four hips (63.8%) showed calcar atrophy, for the most part moderate, most often located in zone 7a. Proximal stress shielding, at the level of the greater trochanter, was reported for 25 hips (36.2%). Cortical thickening was noted in 19 cases (27.5%). It was present simultaneously in zones 3 and 5 in 10 cases and was isolated in zone 3 in seven cases and in zone 5 in two cases. Our statistical analysis did not correlate cortical thickening with metaphyseal sizing and femoral stem position. Reactive lines were observed for 29 cases (42%), but only in the smooth zones that were not coated with HA. Twenty-six cases (37.7%) had a stable pedestal (with no adjacent radiolucent line as described by Engh et al. [20]). Its presence was not correlated with reactive lines (p < 0.01).

Early implant migration was observed in one case, in a woman who presented a Vancouver AL femoral periprosthetic fracture that was fixed without changing the femoral implant, at the 3rd postoperative month. One case of radiolucent line in zones 2 and 7, with no stem destabilization,
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Figure 1
Survival curve of ABG-1™ cups. End-point criterion: cup revision for any reason.

Figure 2
Survival curve of ABG-1™ stems. End-point criterion: stem revision for any reason.

was noted during implantation in a 72-year-old patient who had had a cup change at the 106th month after surgery. Perifemoral osteolysis was observed on X-rays. This involved granulomas concentrated in the metaphyseal zones only, with no diaphyseal extension. They were observed in zone 1a, occasionally in zones 1a and 1b, in 65.2% of the cases, and in zone 7a in 18.8% of the cases. No distal osteolysis underlying the osteointegration zone related to the presence of HA coating was observed.

Survival analysis

At 13 years, the implant survival rate, calculated using the Kaplan-Meier method [22] with a 95% confidence interval, was 80.5% (range, 70.8—91.5) for the overall series. It was 83.2% (range, 74—93.5) for the cup (Fig. 1) and 94.3% (range, 88—100) for the stem (Fig. 2).

Discussion

Several authors have already evaluated the ABG-1™ implants at the medium term [1—10]. They agree on the good clinical and radiological results, including notably the regular presence of good osteointegration on the images. However, Blacha [6] and Delank et al. [7] demonstrated excessive PE wear. A large number of acetabular revisions for PE wear and pelvic osteolysis had already been reported in a medium-term series [6,7,10], leading these authors to abandon the ABG-1™ cup and to recommend increased radiological monitoring of patients who had received these
implants. At 13 years of follow-up, our series also confirms the high proportion of pelvic osteolysis (48.5%), although with no cup destabilization at the long term.

The appearance of osteolysis is multifactorial: among the influential factors, the modularity of the implant is a determining factor. Indeed, Fehring et al. [23] as well as Young et al. [24] estimated that this osteolysis can lead to a problem of the insert in PE conforming to the metal-back. If this means a dissatisfactory insert blocking system, particularly in rotations [24,25], a micromobility between the prosthetic components is present at this interface and produces abrasive wear of the PE on the internal part of the metal-back. The ABG-1™ cup blocking system, with two “olives,” could be considered insufficient and was modified in the ABG-2™ second-generation implants that appeared in October 1996. This wear can also be increased by the presence of screw holes [25,26] (Fig. 3). For Aspengren et al. [27] and Young et al. [24], this micromobility in the acetabular component allows drainage of the joint space fluid loaded with PE debris. During hip movements, a pumping mechanism is created that expels this fluid under pressure, through the screw holes of the metal-back, thus creating the formation of lytic granulomas. For Barrack et al. [26], this phenomenon seems increased by the presence of screws inserted to stabilize the cup during initial implantation.

In this series, the systematic use of a PE insert with an antidislocation rim can also be blamed for the onset of osteolysis lesions. For Herrera et al. [10], this feature is responsible for additional PE wear from a posterior impingement between the prosthetic femoral neck and this rim. Examination of our explants confirms this theory, with the presence of a notch on the rim (Fig. 4). Moreover, these repeated posterior contacts can produce an abnormal movement of the prosthetic head within the insert, thus increasing its wear as well as the movements between the insert and the metal-back [28].

The characteristics of the PE insert itself can also be blamed in the onset of osteolysis. Gamma irradiation sterilization in ambient air causes the PE to reticulate but encourages the creation of free radicals and its oxidation, essentially in its discharged zones [29—31], thus reducing its quality and mechanical resistance [32,33] to the penetration of the prosthetic head. The systematic use in our series of 28 mm zirconia heads may also have been the source of greater insert wear [34], attributable to an increase in roughness and the loss of head sphericity at the medium term, as also reported by Hernigou et al. [35] upon explant examination.

The high PE wear rate (mean ALW = 0.16 mm/year) observed in our study may also have contributed to the high frequency of osteolysis lesions. Schytzer et al. [36] proved that for a mean ALW greater than 0.1 mm/year, osteolysis was systematically present. Some authors [26,28,37] indicate that the follow-up has an incidence on visualizing these granulomas, which are very rarely detected before the 4th year [26] and are revealed increasingly beginning in the 5th postoperative year [28,37]. The possibility of accentuated PE wear caused by a “third body” — debris of HA particles released in the prosthetic joint at the cup—head interface during implant impaction — advanced by Morscher et al. [38] and Castoldi et al. [9] was later disproved. Increased PE wear was finally related to patient factors such as age, sex, and weight [39,40], as well as the surgical technique such as cup position [41] and the thickness of the PE used [11,41,42]. Our study has not been able to confirm these notions.

Depending on the severity of the lesions, the cup model, and the head bearing system, treatment of pelvic osteolysis is difficult to resolve. Given the difficulty in extracting implants and the substantial damage caused, some authors have proposed isolated changes of the prosthetic bearing system [43,44] with or without filling the osteolytic lesions. Other authors have suggested cementing a new PE insert within metal-back cups left in place [45,46]. This therapeutic solution was not retained in our experience and we decided to remove the cup each time because of the ease of extracting it so as to clean out and fill the lesions with morselized bone grafts, which explains the high rate of cup changes in our series. Replacing these implants with an uncremented cup of a slightly larger diameter allowed us to come close to a primary implant technique (Fig. 5A—C).

The quality of the ABG-1™ femoral implant osteointegration observed in this series was very satisfactory (a single case of aseptic implant loosening). This can be explained
by the anatomic design of the implants and the use of HA coating. For Vidalain [47], the essential condition to obtain implant osteointegration is obtaining faultless primary stability. This is encouraged by the anatomic design of the ABG-1™ femoral stem in which its conformation and diaphyseal reaming of the femur at implantation provided ensured stability only in the metaphyseal zone. Femoral filling and stem positioning did not seem to influence the implants' osteointegration in our study.

Moreover, the use of HA as a bioactive material to ensure secondary bone anchorage of the implants has shown its innocuousness in terms of inflammation, allergy, toxicity, and carcinogenicity [48,49]. Bone remodeling at contact with an implant coated with HA begins in the 3rd postoperative week, without fibrous material intervening between the host bone and the prosthesis, according to Hardy et al. [50]. This osteointegration took place for all ages of patients, hip arthrosis etiologies, implanted femur morphology, proximal femoral metaphyseal filling, and implant position in our series. This association of a HA coating and the anatomic design of the femora stem ensure long-term suitable transmission of the stress forces in the implanted bone with no impingement or diaphyseal intolerance. No thigh pain was found in this study.

The appearance of bone bridges (spotwelds), characterizing this osteointegration, in zones 3 and 5 are a demonstration of this progressive passage of stress forces between the implant and the bone over time, as previously reported by Tonino et al. [3,4] and Herrera et al. [10]. These authors report that osteointegration began in a high metaphyseal zone, in the first years after implantation, then migrated toward lower metaphyseal zones, following the 5th year after implantation, without going beyond the lower limit of the HA coating.

This transfer of the proximal forces into distal forces on the femur can be associated with different bone modifications on the radiographs. Cortical thickening was found in the relatively early postoperative period in the diaphyseal zone (27.5%) in our series. It is generally present in Grune zones 3 and 5 [18] but absent on lateral images. It can be monocortical over the short term, depending on the implant position, but it progressively disappears at the medium term and does not indicate a conflict between the stem's tail and the bone, nor inappropriate implant size, according to Tonino et al. [3]. In our study, the presence and location of this cortical thickening were not correlated with oversizing or femoral implant position. Proximal stress shielding can frequently be observed, in 55–74% of cases, depending on the series, at the medium and long term [1,7]. It can result from a number of conditions: preoperative bone density, funnel-shaped femur morphology, implant position, and transfer of forces [7]. Our series demonstrated no relation between this phenomenon of bone demineralization and these parameters. The absence of thigh pain at follow-up confirms the primary stability and the osteointegration capabilities of the ABG-1™ implant.

The presence of clearly delimited osteolytic lesions, located only on the intra-articular femoral part (in zones 1a and 7a), stopped by horizontal trabecula at the implant's shoulder (zone 1b) and diagonal in zone 7b, where the implant's HA coating begins, demonstrate sealed circumferential osteointegration of the implant to the bone, acting like a barrier preventing any distal migration of PE wear particles in the gap zones [4]. This series showed no major proximal osteolysis of the femur and no osteolysis around the implant in the diaphyseal zone.

**Conclusion**

Reporting the long-term clinical and radiological results of ABG-1™ implants used in primary implantation for THAs underscores the frequency of retroacetabular osteolysis. The lack of predictive criteria for its occurrence and the
lack of symptoms encourages us to propose regular monitoring of these patients after 10 years of implantation as well as early preventive acetalubar revision when progressive osteolysis occurs. The cup extraction technique is simple, since it saves bone stock and therefore, in most cases, allows placement of a new cementless cup. This study also confirms the excellent long-term stability of the ABG-1™ anatomic femoral stems and the advantages of its use for any quality of femur bone, in both the young active subject and the older osteoporotic patient.

Conflicts of interest

G. Asencio: Conferences, invitations by Stryker as a speaker. Member of the design group for the ABG system since 2006.

References

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