Orthopaedics & Traumatology: Surgery & Research 101 (2015) 661–665

Available online at

ScienceDirect

www.sciencedirect.com

Elsevier Masson France

EM|consulte

www.em-consulte.com/en

Original article

Excellent short-term results of hip resurfacing in a selected population of young patients

A. Lons [a,c], A. Arnould [a,d], T. Pommepuy [a,c], E. Drumez [a,e], J. Girard [a,b,c,*]

[a] Université Lille Nord de France, 59000 Lille, France
[b] Département de médecine du sport, faculté de médecine de Lille, université de Lille 2, Lille, France
[c] Service d'orthopédie C, hôpital Salengro, place de Verdun, CHU de Lille, 59000 Lille, France
[d] Service d'orthopédie D, hôpital Salengro, place de Verdun, CHU de Lille, 59000 Lille, France
[e] Unité biostatistiques pôle santé publique, maison régionale de la recherche clinique, CERIM, 154, rue du Docteur-Yersin, 59000 Lille, France

ARTICLE INFO

Article history:
Received 16 March 2015
Accepted 17 July 2015

Keywords:
Femoral head diameter
Hip resurfacing
Ion levels
Survival

ABSTRACT

Background: Hip resurfacing (HR) is an alternative option to total hip arthroplasty (THA) in a population of selected patients (young and/or active).
Hypothesis: The short-term survivorship rate is as least as good as that for THA with no abnormal increase in serum metal ion levels.
Materials and methods: A continuous prospective series of 502 hip resurfacings in 481 patients mean age 48.7 years old (±10.3; 18–68) (Conserve Plus, Wright Medical Technology) was analyzed clinically, radiologically and biologically (total blood chrome, cobalt and titanium metal ion levels). Mean follow up was 4.1 years (1.9–4.9).
Results: There were no dislocations. There were 5 cases of revision surgery with component replacement (including 2 infections). Implant survivorship using implant removal as the criteria (excluding infection) was 99.4% at 4 years (CI 95%: 98.1–99.8). The evaluation of metal ion levels showed a significant increase in cobalt from a preoperative level of 0.24 μg/L (0.01–3.6) to 0.86 μg/L (0.01–5.7) at the final follow-up ($P < 0.001$). Chrome and titanium levels went from 0.68 μg/L (0.01–4.4) and 2.36 μg/L (0.39–7) to 1.28 μg/L (0.1–5.5) and 4.49 μg/L (1.29–8.21) respectively ($P < 0.001$). All clinical scores had significantly improved at the final follow-up. Mean frontal plane cup inclination was 42.7° (35–62).
Discussion: In a selected population of young and/or active patients, the short-term results of hip resurfacing are excellent. At the postoperative 4-year follow-up the rate of complications (in particular the absence of dislocations) was less than that for THA in young and/or active patients. Certain conditions must be respected to obtain these results; frontal plane cup inclination of between 40 and 45°, a femoral head diameter of at least 48 mm and good quality femoral bone.
Level of evidence: IV.

1. Introduction

Hip resurfacing with second generation metal on metal bearings was developed 15 years ago to provide an alternative option to total hip arthroplasties (THA) in a population of young and/or active patients. This option has numerous theoretical advantages: return to high level impact sports [1], preservation of femoral and acetabular bone stock [2], lack of instability [3], preservation of articular proprioception [4], maintenance of coxofemoral biomechanics [5,6], maintenance of lower limb length and facilitation of future revision surgery.

However in 2015, although the general notion of HR is accepted there are still numerous controversies; about the type of bearings (large diameter metal on metal bearings) with a risk of adverse reactions to metal debris (ARMD), about the indications and the technical difficulties of implantation [7]. The goal of this study was to analyze the short-term clinical, radiological and biological results of HR in a prospective series of patients.

The main hypothesis was that the short-term survival of HR is equivalent to THA with no abnormal increase in serum metal ion concentrations.

* Corresponding author. Service orthopédie C, faculté de médecine de Lille 2, domaine médecine et sport, CHRU centre hospitalier régional universitaire de Lille, 2, avenue Oscar-Lambret, 59037 Lille cedex, France.
E-mail address: j_girard_lille@yahoo.fr (J. Girard).

http://dx.doi.org/10.1016/j.otsr.2015.07.011
1877-0568/

2. Materials and methods

This was a continuous prospective study was performed in patients who underwent HR over a period of 2 years (January 1, 2009 to December 31, 2010) by a single surgical approach (posterolateral) and one experienced surgeon responding to Haute Autorité de santé (HAS) criteria (more than 50 HR/year) (JG). The contraindications to HR were: a preoperative leg length discrepancy of more than 1 cm, renal insufficiency, age over 70 years old for men and 60 for women, the presence of a bone cyst of the femoral head of more than 1 cm in diameter and a native femoral head diameter of less than 48 mm [3].

The implant used was HR Conserve Plus (Wright Medical Technology, Arlington, TN, USA). The femoral component was cemented in all cases (coat of cement 0.5 mm thick) with size increments of 2 mm. Cup thickness was 3.5 mm (open angle 170°) implanted by 1 mm press fit. Cementless acetabular component fixation was obtained by a porous bead coating. Articular clearance was 150 μm.

A posterolateral approach was used by performing a "T" capsulotomy [8]. The diameter of the patient's native femoral head was measured and served as a reference for the component diameters. The femoral procedure was performed first followed by the acetabular procedure. The femoral head was translated in front of the acetabulum. Reaming was performed until bleeding subchondral bone was obtained. Cup inclination was 40° and anteversion was obtained by placing the cup parallel to the transverse ligament. The femoral component was sealed with low viscosity cement. A redon drain was left in place for 24 hours. Full weight bearing was allowed immediately after surgery. Four weeks of postoperative rehabilitation was systematically prescribed. Patients were seen 2 months after surgery then yearly thereafter.

The clinical evaluation was based on the Postel Merle d'Aubigné score [9], the Harris Hip Score [10], the Oxford hip score [11] the Devane activity classification [12] and UCLA [13]. Standard X-rays (lower limbs. 15° internal rotation) were obtained at each visit. AP X-rays were considered to be valid if the end of the coccyx was centered and located between 2 and 4 cm from the pubic symphysis [14]. A Dunn view was obtained for sagittal assessment. The X-ray evaluation was based on an assessment of frontal plane acetabular cup inclination in relation to the radiographic U-figure (tear drop), the preoperative cervico-diaphyseal angle and the SSA (Stem Shaft Angle) at follow up as well as calculation of anterior offset on the Dunn view. The presence of heterotopic ossifications was evaluated according to Brooker et al. [15]. The appearance of radiolucencies (of more than 2 mm) or acetabular osteolysis was identified.

A biological analysis of the chrome, cobalt and titanium metal concentrations was performed on whole blood by mass spectrometry (High Resolution Sector Field Inductively Coupled Plasma Mass Spectrometer (HR-SF-ICPMS)). Analysis was based on preoperative doses and another at the final follow-up. The limits of detection were 0.1 μg/L for 3 ions.

The series included 481 patients (502 HR, 21 bilateral cases) including 70% men (335 patients) and 30% women (146 patients). The mean age was 48.7 (±10.3; 18-68). The mean BMI was 26.1 (±488; 15.1–47.3). Surgery lasted a mean 63.5 minutes (±14.6; 30–140). The mean size of the femoral and acetabular components was 50.4 mm (48-60) and 56.4 mm (54–66) respectively. The etiologies were mainly primary osteoarthritis of the hip (72.8%), dysplasia (13.1%), aseptic osteonecrosis of the femoral head (8%), post-traumatic causes (3.7%) and sequella from osteochondritis (2.4%).

At the final follow up, one lost to follow-up patient (0.2%) and 6 patients who were living overseas who were evaluated by a self-administered questionnaire and email were noted. There were therefore 474 patients who underwent all evaluations (radiological, biological and clinical). The mean follow-up was 4.1 years (1.9–4.9).

Fig. 1. Pelvic AP X-ray in a 41 year old man with primary osteoarthritis of the hip centered on the right hip.

3. Statistical method

The Student *t* test and the Chi-square test were used for continuous and categorical variables respectively and the Wilcoxon test for non parametric data. The correlation between the progression of metal ion concentrations and a numerical parameter was studied with the Spearman correlation coefficient and the Mann-Whitney test for binary qualitative variables. Confidence intervals (CI) were determined at 95% and $P < 0.05$ was considered to be statistically significant. Kaplan-Meier type survival curves were obtained based on component replacement for whatever reason, including septic revision, as criteria for failure (CI 95%).

4. Results

There were no dislocations. A postoperative hematoma had to be evacuated with no other clinical consequences. Three cases of Brooker class III heterotopic ossifications (0.6%) were noted.

Survivorship based on revision surgery for any cause as the criteria for failure was 99% at 4 years (CI 95%: 97.6-99.6) and 99.4% at 4 years (CI 95%: 98.1–99.8) (Figs. 1 and 2) when component removal

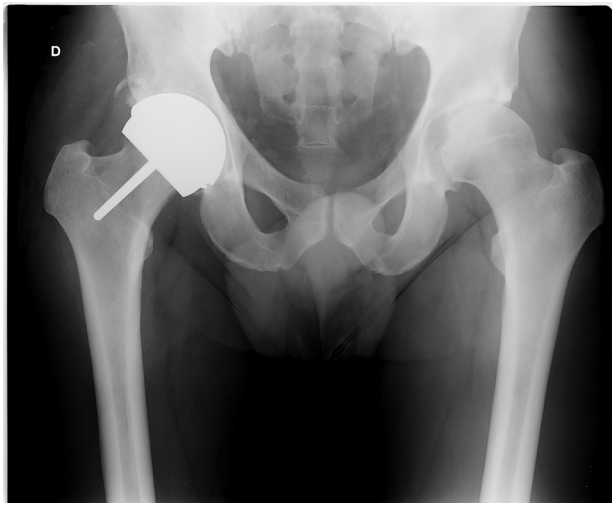

Fig. 2. Postoperative 4 year AP X-ray of the pelvis. Frontal plane cup inclincation is 43°, the cervico-diaphyseal angle is 130° and the SSA angle is 132°. There are no radiolucencies.

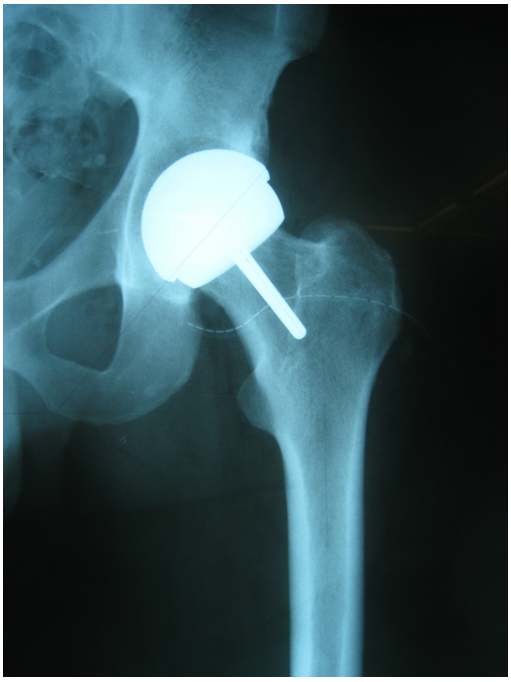

Fig. 3. Postoperative AP X-ray of the left hip. The orientation of the acetabular cup is good (frontal plane inclination 41°) but there is a large gap.

was the criteria (excluding infection) There were 5 revisions with replacement (0.9%) with 2 one-stage revisions for infection (0.4%), 2 femoral loosenings (0.4%) and 1 tilt of the acetabular cup (0.2%) (Figs. 3 and 4). One revision was performed without component replacement to remove Brooker class III heterotopic ossifications causing stiffness.

Evaluation of metal ion levels showed a significant increase in cobalt concentrations, which went from a preoperative rate of 0.24 μg/L (0.01–3,6) to 0.86 μg/L (0.01–5.7) at the final follow-up ($P < 0.001$). Preoperative chrome and titanium concentrations also increased from 0.68 μg/L (0,01–4.4) and 2.36 μg/L (0.39–7) respectively to 1.28 μg/L (0.1–5.5) and 4.49 μg/L (1.29–8.21) at the final follow-up ($P < 0.001$) respectively. There were no correlations found between ion concentrations and the following parameters: age, sex, BMI, etiology, UCLA score, Devane score, cup inclination, SSA angle or component size.

Fig. 4. At 2 months, the cup has shifted (inclination 12°) resulting in cup-femoral neck contact. This caused femoral neck notching and required surgical revision.

Table 1
Progression of clinical scores from the preoperative assessment to the final follow-up (mean, range).

	Pre-op	Follow up	*P*
PMA	10.5 (5–16)	17.5 (11–18)	<0.0001
Range of motion	3.5 (1–6)	6 (3–6)	<0.0001
Function	3 (1–6)	5.5 (3–6)	<0.0001
Pain	4 (0–5)	6 (3–6)	<0.0001
Harris Hip Score	31.5 (22–78)	97 (50–100)	<0.0001
Oxford	37 (27–55)	14.5 (12–28)	<0.001
Devane	2.5 (1–5)	4 (1–5)	<0.001
UCLA	5 (2–10)	7 (2–10)	<0.001

Table 2
Progression of joint range of motion from the preoperative assessment to the final follow-up (mean, range) expressed in degrees.

	Pre-op	Follow-up	*P*
Flexion	81 (55-130)	121 (75–140)	<0.0001
Extension	−5 (−30/30)	10 (−5/40)	<0.001
Rot Ext	−2.5 (−30/40)	20 (10/50)	<0.0001
Rot Int	0 (−20/40)	20 (20/50)	<0.001
Abduction	30 (0/50)	37.5 (10/50)	<0.001
Adduction	25 (0/40)	32.5 (20/50)	<0.001
Global	127.5 (50–130)	240 (110–300)	<0.0001

All the clinical scores significantly improved with a mean final PMA score of 17.5 (11–18) and an HHS of 97 (50–100) (Table 1). Four young patients (under 25) with severe neurological diseases had poor clinical scores (Harris score between 50 and 60) and Devane score between 1 and 2. Articular range of motion was significantly increased in all sectors (Table 2).

Mean frontal plane cup inclination was 42.7° (35–62) (Figs. 1 and 2). Inclination was greater than 55° in four cups (0.8%). The CCD angle was 132.5° (111–160). The femoral component was implanted with slight valgus, with an SSA of 134.3° (112–171). Anterior offset of the femoral component was 6.9 mm (−8–20).

5. Discussion

HR is an interesting alternative to conventional THA in a population of young and/or athletic patients [16,17]. If the indications are followed and surgery is well performed, the HR survival rate at 4 years is comparable to that of THA. To obtain these results, the femoral component must be at least 48 mm, frontal plane cup inclination should be 40° and patients with poor quality bone should be excluded [18]. The numerous advantages of the HR procedure must be considered in relation to possible disadvantages such as the use of a large diameter head metal on metal bearing [18]. However, no abnormal increase in metal ion concentrations was observed in our study.

There are several limitations to this study. Indeed six patients (1.2%) could not undergo radiological and biological evaluation, however this small group of cases did not seem to influence the conclusions. Moreover only one type of HR system was evaluated. However, this was one of the 2 systems approved for use on the French market (with the Birmingham Hip Resurfacing [BHR]) by the HAS. Then, a study evaluating a single HR system seemed to be pertinent to reduce any interpretation bias (in particular biological). The mean follow-up was too short to draw long-term conclusions. However the low rate of early complications in our series is similar to THA results. The risk of later complications (after more than 5 years) should be evaluated with longer follow-up.

Comparison of HR and THA survivorship rates was performed by analyzing various national registries. Thus, in the Swedish registry [19] the 5-year survivorship of THA is 95.7%. In the same way in the Australian registry of 266 645 THA, the rate of revision surgery at 5

years is 4.9% (4.5–5.2) [20]. In this register, the rate of HR revision is only 4.1% at 5 years. Moreover, if we limit our analysis to HR with a diameter of more than 48 mm (as in our series), the revision rate is only 2.7% (2.0–2.9). The Anglo-Welsh registry confirms these data in an analysis of 539 372 THA [21]. The 5-year revision rate is 5.6% (5.1–5.9) for THA and 2.8% (2.3–2.9) in the HR group with a diameter of more than 48 mm. The revision rate of less than 1% at 4 years observed in our series confirms these results and is a sign of the excellent survivorship rate reported in the registers in head diameters of more than 48 mm.

Like in most other HR series, there were no dislocations observed in our series [22–24]. This must be compared to the different rates observed after THA, which depend on numerous factors including one of the most important, which is the diameter of the femoral head [25]. Respecting the diameter of the native femoral head diameter during HR prevents the risk of dislocation, while it is impossible to reproduce the anatomy of the femoral head with THA. It should be noted that in young patients, the risk of instability caused by THA results in apprehension about performing physical activities and sports [26]. The absence of the risk of instability as well as the preservation of femoral neck proprioceptors and femoral offset, explains the better return to sports and physical activities following HR than THA [27]. This has been found in high impact sports (running [1]) and in a prospective randomized study [23].

The production of metal ions is inherent to the introduction of a metal foreign body that produces passive corrosion. Thus, a knee prosthesis results in the production of chromium and cobalt ions secondary to the extensive contact of the femoral component with the synovial fluid. For Lueztner et al. [28], cobalt concentrations with a unilateral THA are 3.3 μg/L (and 4.3 μg/L for bilateral THA) or 3.8 times more than in our series. The same remark can be made for spine surgery whose material generates high metal ion concentrations (in particular titanium) that have no clinical consequences [29].

The ion concentrations in the literature following HR vary. Indeed, this depends on numerous factors: the types of implant, the type of bearing (cast or forged), cup design, articular play... [16,17,30,31]. For the HR Conserve+ the mean metal ion levels (in whole blood) are approximately 1 to 1,7 μg/L for chrome and 1.2 to 1.9 μg/L for cobalt [24,32–34]. The ion concentrations in our series were slightly lower. This is probably due to the low mean cup inclination (42°), which improves the contact patch to rim distance to more than a centimeter [18]. It has been shown that an ideal cup position with an inclination of 39.7° and 14.9° anteversion in a 56 mm cup minimized metal ion production [35]. This is very close to the data in our series thus explaining the low levels of metal ions. The quality of proximal femur bone is a key point that must be perfectly managed before performing HR [36]. Thus there are numerous contraindications to HR, first osteoporosis, which explains the age difference between men and women in this series. The practice of systematic osteodensitometry in women following menopause prevents this risk [37]. Thus, etiologies resulting in poor bone quality are also contraindications to HR: inflammatory arthritis, voluminous aseptic osteonecrosis, bone cysts of the femoral head larger than 1 cm, and diseases that result in significant deformity of head/neck junction [38,39].

6. Conclusion

The excellent clinical results of HR are confirmed in a selected population of young and/or active patients. After a mean 4 years of follow-up the complication rate is low with survivorship in 99%. Certain conditions must be fulfilled: frontal plane cup inclination between 40 and 45°, a femoral head diameter of at least 48 mm and good femoral bone quality. Moreover to prevent tribological problems of large head diameter metal on metal couples, we recommend using one of the two HR systems that have been on the French market for more than 15 years (Conserve Plus and BHR).

Disclosure of interest

Pr Julien Girard: Microport, Smith and Nephew, B. Braun.

The other authors declare that they have no conflicts of interest concerning this article.

References

[1] Fouilleron N, Wavreille G, Endjah N, Girard J. Running activity after hip resurfacing arthroplasty: a prospective study. Am J Sports Med 2012;40:889–94.
[2] Amstutz HC, Beaule PE, Dorey F, Campbell PA, Gruen TA. Metal-on-metal hybrid surface arthroplasty: two to six year follow-up. J Bone Joint Surg Am 2004;86:28–39.
[3] Pailhe R, Matharu GS, Sharma A, Pynsent PB, Treacy RB. Survival and functional outcome of the Birmingham Hip Resurfacing system in patients aged 65 and older at up to ten years of follow-up. Int Orthop 2014;38:1139–45.
[4] Szymanski C, Thouvarecq R, Dujardin F, Migaud H, Maynou C, Girard J. Functional performance after hip resurfacing or total hip replacement: a comparative assessment with non-operated subjects. Orthop Traumatol Surg Res 2012;98:1–7.
[5] Girard J, Lavigne M, Vendittoli PA, Roy AG. Biomechanical reconstruction of the hip: a randomised study comparing total hip resurfacing and total hip arthroplasty. J Bone Joint Surg Br 2006;88:721–6.
[6] Silva M, Lee KH, Heisel C, Dela Rosa MA, Schmalzried TP. The biomechanical results of total hip resurfacing arthroplasty. J Bone Joint Surg Am 2004;86:40–6.
[7] Leclercq S, Lavigne M, Girard J, Chiron P, Vendittoli PA. Durom hip resurfacing system: retrospective study of 644 cases with an average follow-up of 34 months. Orthop Traumatol Surg Res 2013;99:273–9.
[8] Girard J. Le resurfaçage de hanche. EMC, techniques chirurgicales. Orthopédie et traumatologie, 5. Ed. Elsevier Masson; 2013. p. 1–10 [Article 44-660].
[9] Merle d'Aubigné R. Cotation chiffrée de la fonction de la hanche. Rev Chir Orthop 1990;76:371–4.
[10] Harris WH, McCarthy Jr JC, O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. J Bone Joint Surg Am 1982;64:1063–7.
[11] Delaunay C, Epinette JA, Dawson J, Murray D, Jolles BM. Oxford hanche Cross-cultural adaptations of the Oxford-12 HIP score to the French speaking population. Orthop Traumatol Surg Res 2009;95:89–99.
[12] Devane PA, Robinson EJ, Bourne RB, Rorabeck CH, Nayak NN, Horne JG. Measurement of polyethylene wear in acetabular components inserted with and without cement. A randomized trial. J Bone Joint Surg Am 1997;79:682–9.
[13] Naal FD, Impellizzeri FM, Leunig M. Which is the best activity rating scale for patients undergoing total joint arthroplasty? Clin Orthop Relat Res 2009;467:958–65.
[14] Tannast M, Zheng G, Anderegg C, Burckhardt K, Langlotz F, Ganz R, et al. Tilt and rotation correction of acetabular version on pelvic radiographs. Clin Orthop Relat Res 2005;438:182–90.
[15] Brooker AF, Bowerman JW, Robinson RA, Riley Jr LH. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am 1973;55:1629–32.
[16] Amstutz HC, Beaulé PE, Dorey F, Campbell PA, Gruen TA. Metal-on-metal hybrid surface arthroplasty: two to six year follow-up. J Bone Joint Surg Br 2004;86:28–39.
[17] Mertl P, Boughebri O, Havet E, Triclot P, Lardanchet JF, Gabrion A. Large diameter head metal-on-metal bearings total hip arthroplasty: preliminary results. Orthop Traumatol Surg Res 2010;96:14–20.
[18] Yoon JP, Le Duff MJ, Johnson AJ, Takamura KM, Ebramzadeh E, Amstutz HC. Contact patch to rim distance predicts metal ion levels in hip resurfacing. Clin Orthop Relat Res 2013;471:1615–21.
[19] Registre suédois : http://www.shpr.se/Libraries/Documents/AnnualReport_2012_Eng_WEB.sflb.ashx ; 2012.
[20] Registre australien : http://www.dmac.adelaide.edu.au/aoanjrr/publications.jsp ; 2012.
[21] Registre anglo-gallois : http://www.njrcentre.org.uk/njrcentre/Portals/0/Documents/England/Reports/10th_annual_report/NJR 2012.pdf ; 2012.
[22] Lavigne M, Masse V, Girard J, Roy AG, Vendittoli PA. Return to sport after hip resurfacing or total hip arthroplasty: a randomized study. Rev Chir Orthop Reparatrice Appar Mot 2008;94:361–7.
[23] Vendittoli PA, Lavigne M, Roy AG, Lusignan D. A prospective randomized clinical trial comparing metal-on-metal total hip arthroplasty and metal-on-metal total hip resurfacing in patients less than 65 years old. Hip Inter 2006;16:73–81.
[24] Kim PR, Beaulé PE, Dunbar M, Lee JK, Birkett N, Turner MC, et al. Cobalt and chromium levels in blood and urine following hip resurfacing arthroplasty with the Conserve Plus implant. J Bone Joint Surg Am 2011;93:107–17.
[25] Girard J. Femoral head diameter considerations for primary total hip arthroplasty. Orthop Traumatol Surg Res 2015;101:S25–9.
[26] Ollivier M, Frey S, Parratte S, Flecher X, Argenson JN. Pre-operative function, motivation and duration of symptoms predict sporting participation after total hip replacement. Bone Joint J Br 2014;96:1041–6.

[27] Girard J, Miletic B, Deny A, Migaud H, Fouilleron N. Can patients return to high-impact physical activities after hip resurfacing? A prospective study. Int Orthop 2013;37:1019–24.
[28] Luetzner J, Krummenauer F, Lengel AM, Ziegler J, Witzleb WC. Serum metal ion exposure after total knee arthroplasty. Clin Orthop Relat Res 2007;461:136–42.
[29] Ipach I, Schäfer R, Mittag F, Leichtle C, Wolf P, Kluba T. The development of whole blood titanium levels after instrumented spinal fusion. Is there a correlation between the number of fused segments and titanium levels? BMC Musculoskelet Disord 2012;13:159–62.
[30] Delaunay C. Couple de friction métallique de seconde génération en arthroplastie totale primaire non cimentée de hanche. Rev Chir Orthop 2000;86:809–24.
[31] Delaunay C, Petit I, Learmonth ID, Oger P, Vendittoli PA. Metal-on-metal bearings total hip arthroplasty: the cobalt and chromium ions release concern. Orthop Traumatol Surg Res 2010;96:894–904.
[32] Girard J. Is it time for cementless hip resurfacing? Hosp Spec Surg J 2012;8:245–50.
[33] Beaulé PE, Kim PR, Hamdi A, Fazekas A. A prospective metal ion study of large-head metal-on-metal bearing: a matched-pair analysis of hip resurfacing versus total hip replacement. Orthop Clin North Am 2011;42:251–7.
[34] Amstutz HC, Campbell PA, Dorey FJ, Johnson AJ, Skipor AK, Jacobs JJ. Do ion concentrations after metal-on-metal hip resurfacing increase over time? A prospective study. J Arthroplasty 2013;28:695–700.
[35] Mellon SJ, Grammatopoulos G, Andersen MS, Pandit HG, Gill HS, Murray DW. Optimal acetabular component orientation estimated using edge-loading and impingement risk in patients with metal-on-metal hip resurfacing arthroplasty. J Biomech 2015;48:318–23.
[36] Kishida IY, Sugano N, Nishii T, Miki H, Yamaguchi K, Yoshikawa H. Preservation of the bone mineral density of the femur after surface replacement of the hip. J Bone Joint Surg Br 2004;86:185–9.
[37] Gross TP, Liu F. Risk factor analysis for early femoral failure in metal-on-metal hip resurfacing arthroplasty: the effect of bone density and body mass index. Orthop Surg Res 2012;7:1–6.
[38] Daniel J, Pradhan C, Ziaee H, Pynsent PB, McMinn DJ. Results of Birmingham hip resurfacing at 12 to 15 years: a single-surgeon series. Bone Joint J 2014;96:1298–306.
[39] Amstutz HC, Antoniades JT, Le Duff MJ. Results of metal-on-metal hybrid hip resurfacing for Crowe type-I and II developmental dysplasia. J Bone Joint Surg Am 2007;89:339–46.