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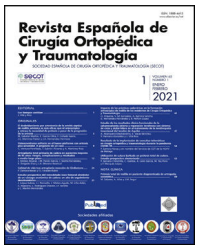

ORIGINAL PAPER

[Translated article] Metal on metal total hip arthroplasty: Correlation between inclination of the acetabular and metal ion levels

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KEYWORDS
Metal–metal hip arthroplasty;
Ions;
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Abstract Due to their low friction index, hip arthroplasties with metal–metal (M–M) friction torque have been an attractive option in young patients with high functional demand, currently they have suffered a decrease in their use due to the complications of some models and physiological reactions adverse reactions related to the elevation of metal ions in the blood. Our objective is to review the patients with M–M pair operated in our centre, correlating the ion level with the position of the acetabular component and with the size of the head.

Material and methods: Retrospective review of 166 M–M hip prostheses operated between 2002 and 2011. Sixty five ruled out for different causes (death, loss of follow-up, no current ion control, no radiography or others), leaving a sample of 101 patients to be analysed. Follow-up time, cup inclination angle, blood ion level, Harris Hip Score (HHS), and complications were recorded.

Results: One hundred and one patients (25 women and 76 men), 55 years of average age (between 26 and 70), of these 8 were surface prostheses and 93 total prostheses. The mean follow-up time was 10 years (between 5 and 17 years). The mean head diameter was 46.25 (between 38 and 56). The mean inclination of the butts was 45.7° (between 26° and 71°). The correlation force between the verticality of the cup and the increase in ions is moderate $r = 0.31$ for Cr and slight $r = 0.25$ for Co. The correlation force between head size and ion increase is weak and inverse $r = -0.14$ for Cr and $r = 0.1$ for Co. Five patients (4.9%) required revision (2 [1%] due to increased ions with pseudotumor). The mean time to revision was 6.5 years in which

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the ions increased. The mean HHS was 94.01 (between 55.8 and 100). In the review of patients, we found 3 with a significant increase in ions who had not followed controls, all 3 had an HHS of 100. The angles of the acetabular components were 69°, 60° and 48° and the diameter of the head was 48.42 and 48 mm, respectively.
Discussion and conclusions: M–M prostheses have been a valid option in patients with high functional demand. A bi-annual analytical follow-up is recommended, since in our case we have detected 3 patients with HHS 100 who presented unacceptable elevation of cobalt >20 μm/l (according to SECCA) of the ions and 4 with very abnormal elevation of cobalt ≥10 μm/l (according to SECCA), all of them with cup orientation angles >50°. With our review we can conclude that there is a moderate correlation between the verticality of the acetabular component and the increase in blood ions and that the follow-up of this patient with angles >50° is essential.

PALABRAS CLAVE
Artroplastia cadera metal-metal;
Iones;
Inclinación acetabular

Artroplastias metal-metal en cadera: correlación entre el aumento de iones y el ángulo del componente acetabular

Resumen Las artroplastias de cadera con par de fricción metal-metal (M-M) debido a su bajo índice de fricción han resultado una opción atractiva en pacientes jóvenes con alta demanda funcional, aunque actualmente han experimentado un descenso en su uso debido a las complicaciones de algunos modelos y a las reacciones fisiológicas adversas relacionadas con la elevación de iones metálicos en sangre. Nuestro objetivo es revisar los pacientes con par M-M intervenidos en nuestro centro, correlacionando el nivel de iones con la posición del componente acetabular y con el tamaño de la cabeza.
Material y métodos: Revisión retrospectiva de 166 prótesis de cadera M-M intervenidas entre 2002 y 2011. Se descartaron 65 por diferentes causas (fallecimiento, pérdida de seguimiento, no control actual de iones, no radiografía u otros), quedando una muestra de 101 pacientes a analizar. Se registró el tiempo de seguimiento, el ángulo de inclinación del cótilo, el nivel de iones en sangre, el *Harris Hip Score* (HHS) y las complicaciones.
Resultados: Ciento un pacientes (25 mujeres y 76 hombres), 55 años de edad media (entre 26-70); de estos, 8 fueron prótesis de superficie. El tiempo medio de seguimiento fue de 10 años (entre 5 y 17 años). La media de los diámetros cefálicos fue de 46,25 mm (entre 38 y 56). La inclinación media de los cótilos fue de 45,7° (entre 26 y 71°). La fuerza de correlación entre la verticalidad del cótilo y el aumento de iones es moderada r = 0,31 para el Cr y leve r = 0,25 para el Co. La fuerza de correlación entre el tamaño de la cabeza y el aumento de iones es débil e inversa r = −0,14 para Cr y r = 0,1 para Co. Cinco pacientes (4,9%) precisaron revisión (2 [1%] por aumento de iones con seudotumor). El tiempo medio hasta la revisión fue de 6,5 años, en los que aumentaron los iones. El HHS medio fue de 94,01 (entre 55,8 y 100). En la revisión de pacientes hallamos 3 con aumento importante de iones que no habían seguido controles, y los 3 presentaban un HHS de 100. Los ángulos de los componentes acetabulares fueron de 69, 60 y 48°, y el diámetro de la cabeza fue de 48, 42 y 48 mm, respectivamente.
Discusión y conclusiones: Las prótesis M-M han sido una opción válida en pacientes con elevada demanda funcional. Un seguimiento analítico bianual es recomendable, ya que en nuestro caso hemos detectado 3 pacientes con HHS de 100 que presentaban elevación inadmisible de cobalto >20 μ/l (según la SECCA) de los iones y 4 con elevación muy anormal de cobalto ≥10 μ/l (según la SECCA), todos ellos con ángulos de orientación del cótilo >50°. Con nuestra revisión podemos concluir que hay una correlación moderada entre la verticalidad del componente acetabular y el aumento de iones en sangre, y que el seguimiento de los pacientes con ángulos >50° es imprescindible.

Introduction

In 1891 the first hip arthroplasty surgery was recorded, and later evolved to become the surgery of the 20th century.[1] It was not until the 1950s that McKee and Watson-Farrar introduced the first metal-on-metal (M–M) total hip arthroplasty.[2] From the year 2000 onwards, M–M torque resurfacing arthroplasty became popular due to its low wear characteristics, especially in young, physically active patients with high demands on implant performance.[3]

In August 2010 a well-known international firm announced a worldwide recall of its M–M hip prosthesis due to an unacceptably high revision rate for this system.[4] The Australian joint registry revealed a revision rate of 9.3% for the ASR total hip arthroplasty system and 10.9% for the ASR hip resurfacing system compared to 3.4% and 4.0%, respectively, for comparable prostheses. Other registries and studies echoed these results, thus highly questioning the M–M friction par.[5,6]

In 2007 the literature was already talking about the correlation between increased blood ion levels and M–M lumbar intervertebral disc implants, and it was then that elevated blood ion levels began to be correlated with prosthetic wear in the hip, suggesting that it could be deduced that factors leading to higher blood ion levels lead to greater wear.[7,8] Several studies suggest that component malpositioning, as measured by acetabular component tilt, correlates with increased wear and thus increased ion levels.[9–11]

Cobalt values $\geq$10 μm/l are indicative of increased joint wear, with a specificity of 100% and a sensitivity of 93%.[12] Cobalt ion concentration above $\geq$20 μm/l has been associated with a risk of systemic intoxication and surgical treatment should be considered in the short term, as recommended by the Spanish Society of Hip Surgery (SECCA).[13]

Our objective was to review the patients with total hip prosthesis with cementless stem and impacted acetabular component with M–M large head bearing pair (greater than 36 mm) and resurfacing arthroplasties operated in our centre, correlating the level of ions with the position of the acetabular component and with the size of the head.

Material and methods

We conducted a retrospective study reviewing 166 M–M hip replacements performed between 2002 and 2011. We discarded 65 cases (death due to causes unrelated to the arthroplasty, loss to follow-up, no current ion control and no X-ray at follow-up), leaving a sample of 101 patients to analyse. We recorded follow-up time, cup inclination angle, blood ion level, Harris Hip Score (HHS) and complications.

All patients underwent an anteroposterior (AP) hip and pelvis radiograph calibrated with a TraumaCad calibration belt as a calibration marker (BrainLab Ltd., Petach-Tikva, Israel) (Fig. 1).

The statistical package for social science statistics software SPSS v22 (SPSS Inc., Chicago, IL, USA) was used to calculate the correlation between head size and cup inclination angle with blood ion level.

Possible correlations between blood metal ions with prosthetic head diameter or acetabular angle inclination were assessed with Spearman's correlation coefficient.

Figure 1 Total hip prosthesis with M–M bearing pair.

Table 1 Mean sample data on the different parameters analysed.

Sex	25 women, 76 men
Age	55 years (26–70)
Follow-up	10 years (5–17)
Harris Hip Score	94 (55.8–100)
Cephalic diameter	46 (38–56)
Cup tilt	45 (26–71)

Results

A total of 101 patients (76 men) were evaluated, with a mean age of 55 years (between 26 and 70); of these, 8 were surface prostheses and 93 were total prostheses. The mean follow-up time was 10 years (between 5 and 17 years). The mean HHS was 94.01 (between 55.8 and 100). Mean head diameters were 46.25 mm (between 38 and 56). The mean cup inclination was 45.7 (between 26 and 71) (Table 1).

The correlation strength between the verticality of the cup and the increase of ions was moderate (r = .31) for Cr and slight (r = .25) for Co. The strength of correlation between head size and ion enhancement was weak and inverse: r = .14 for Cr and r = .1 for Co (Fig. 2).

Of the patients reviewed in the study, 5 of them (4.9%) required surgical revision of the prosthesis. The reasons were: 2 due to increased ions with pseudotumour on MRI, one due to periprosthetic fracture, one due to aseptic loosening and one due to recurrent subluxation. The latter had an angle of inclination of 70. The mean time to revision was

Table 2 Data on patients with elevated ions, degrees of acetabulum tilt and ion levels.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Cup angle	60°	69°	48°	55°	60°
Chromium level, μm/l	100	84	42	104	97
Cobalt level, μm/l	97	88	109	158	50

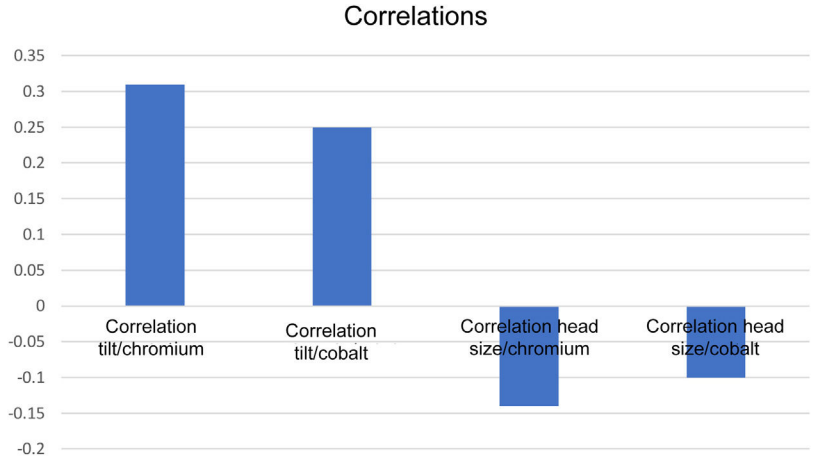

Figure 2 Plot of correlations between blood ion levels and cup tilt or between ion level and head size.

6.5 years in those cases where the cause of revision was elevated serum ion levels.

The analysis showed 5 patients with increased cobalt ion levels above 20 μm/l, with this elevation being a recommendation for bearing replacement. Two of the 5 cases were replaced, one due to aseptic loosening of the acetabulum, with partial replacement, and the other due to subluxations, with total replacement due to the impossibility of separating the head from the stem, resulting in block removal after osteotomy. The other 3 with a significant increase in ions that had not followed controls had an HHS of 100. The angles of the acetabular components were 69, 60 and 48, and the head diameter was 48.42 and 48 mm, respectively (Table 2).

Discussion and conclusions

M–M bearing couple prostheses are a valid option in young patients with high functional demand. In our analysis we found a tendency for elevated ions in patients with higher tilt angle cups despite optimal prosthesis functionality (HHS 100). Due to the higher reported rate of early revision and elevated serum levels of cobalt and chromium in the blood, with their possible toxicological effects, concern about this M–M pair increased.[14]

A systematic review and meta-analysis of trials where differences for serum blood ion levels were calculated can be found in the literature. The mean differences for serum chromium and cobalt metal ions were not significantly different between hip resurfacing and M–M total hip arthroplasty patients, although there was a trend towards lower serum cobalt ion levels in patients receiving hip resurfacing prostheses.[15]

Authors looking at resurfacing prostheses, such as De Haan et al.[9] and Langton et al.[11] agree with us that abduction angles greater than 55°, combined with small component size, result in higher serum levels of cobalt and chromium ions, justifying that this is likely due to an increased risk of rim loading. Hart et al.[10] also concur in their study on the relationship of acetabular component inclination and add that acetabular component anteversion has a weak association with increased ions as measured on computed tomography.

However, other studies suggest that blood metal ion levels and acetabular component positioning are not directly related.[16,17] Mann et al.[18] found no relationship between the position of the acetabular component or femoral stem and elevated blood ions in a prospective study following 114 patients undergoing M–M hip resurfacing arthroplasty. Similarly, Hart et al.[19] studied 138 patients who underwent revision M–M hip resurfacing arthroplasty, analysing the components removed at revision surgery by looking at the type of wear at both the head and the edge of the socket and correlating it with preoperative data, and after multivariate analysis found that the most important predictor of wear rate was the presence of loading at the socket edges, but contrary to expectations, 69% of the hips had an angle of inclination <55°.

With regard to head size, most studies suggest that there is no relationship.[20,21] In our study, there is a weak inverse correlation, suggesting that if there were a relationship, it would be favourable to opt for smaller head sizes. Smith et al.[22] mention in their article that they strongly believe that there is a relationship between high ions and large prosthetic head size.

Table 3 Follow-up recommendations for patients wearing metal-on-metal bearing prostheses.

	Metal-on-metal surface prosthesis except ASRTM (Depuy®)		Metal-on-metal hip prosthesis of ASRTM (Depuy®) brand (all models)		Metal-on-metal total hip prosthesis with heads <36 mm in diameter		Metal-on-metal total hip prosthesis with heads ≥36 mm in diameter	
	Asymptomatic patient	Symptomatic patient	Asymptomatic patient	Symptomatic patient	Asymptomatic patient	Symptomatic patient	Asymptomatic patient	Symptomatic patient
Chronology of follow-up visits	In accordance with local protocols. Annual in women or sizes <48 mm	Annual for 5 years at least	Annual, for duration of implant life	Annual, for duration of implant life	In accordance with local protocols, annual in women	Annual for 5 years at least	Annual, for duration of implant life	Annual, for duration of implant life
MRI, ultrasound or CT scan, without artefacts	No need	Recommended in all cases	Recommended in all cases	Recommended in all cases	No need	Recommended in all cases	Recommended if metal ions increase	Recommended in all cases
CBC including Co–Cr ions	Not required but there is debate. Recommended for women	Recommended in all cases	Recommended in all cases	Recommended in all cases	Not required but there is debate. Recommended for women	Recommended in all cases	Recommended in all cases	Recommended in all cases

The follow-up of these patients is a hotly debated topic. Hernández-Vaquero et al.[23] indicate that in asymptomatic patients with stable blood ion levels in the medium and short term, annual blood ion levels would not require annual blood tests. The SECCA provides action plans that differentiate according to whether the parameters are prosthetic or clinical (Table 3).[13]

The limitations of our study would be its retrospective nature, with the consequent loss of patients. Another limitation could consist of having considered two types of prosthesis in the same group, following the publications of Kuzyk et al.,[15] where they report that the mean differences for serum chromium and cobalt metal ions were not significantly different between patients with hip resurfacing prostheses and patients with M–M total hip arthroplasty, which should not be a factor that altered our results but should be taken into consideration.

A biannual analytical follow-up is recommended, as in our case we detected 3 patients with HHS 100 presenting with inadmissible cobalt elevation >20 μm/l (according to SECCA) of ions and 4 with very abnormal cobalt elevation ≥10 μm/l (according to SECCA), all of them with cup orientation angles >50°.

From our review we can conclude that there is a moderate correlation between the verticality of the acetabular component and the increase in blood ions, and that the follow-up of patients with angles >50° is essential.

Level of evidence

Level of evidence III.

Funding

No funding of any type was received for this study.

Conflict of interests

All authors declare that there is no conflict of interest that could have biased or influenced their actions or the outcome of the study.

Right to privacy and informed consent

The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is held by the corresponding author.

Ethics committee approval

Approved by the hospital ethics committee.

References

1. Law JI, Crawford DA, Adams JB, Lombardi AVJ. Metal-on-metal total hip revisions: pearls and pitfalls. J Arthroplasty. 2020;35:S68–72.
2. McKee GK, Watson-Farrar J. Replacement of arthritic hips by the McKee-Farrar prosthesis. J Bone Joint Surg Br. 1966;48:245–59.
3. Anissian HL, Stark A, Gustafson A, Good V, Clarke IC. Metal-on-metal bearing in hip prosthesis generates 100-fold less wear debris than metal-on-polyethylene. Acta Orthop Scand. 1999;70:578–82.
4. Wienroth M, McCormack P, Joyce TJ. Precaution, governance and the failure of medical implants: the ASR™ hip in the UK. Life Sci Soc Policy. 2014;10:19.
5. De Steiger RN, Hang JR, Miller LN, Graves SE, Davidson DC. Five-year results of the ASR XL acetabular system and the ASR hip resurfacing system: an analysis from the Australian Orthopaedic Association National Joint Replacement Registry. J Bone Joint Surg Am. 2011;93:2287–93.
6. Steele GD, Fehring TK, Odum SM, Dennos AC, Nadaud MC. Early failure of articular surface replacement XL total hip arthroplasty. J Arthroplasty. 2011;26 Suppl. 6:14–8.
7. Zeh A, Planert M, Siegert G, Lattke P, Held A, Hein W. Release of cobalt and chromium ions into the serum following implantation of the metal-on-metal Maverick-type artificial lumbar disc (Medtronic Sofamor Danek). Spine (Phila Pa 1976). 2007;32:348–52.
8. Bauer TW, Shanbhag AS. Are there biological markers of wear? J Am Acad Orthop Surg. 2008;16 Suppl. 1:S68–71.
9. De Haan R, Pattyn C, Gill HS, Murray DW, Campbell PA, de Smet K. Correlation between inclination of the acetabular component and metal ion levels in metal-on-metal hip resurfacing replacement. J Bone Joint Surg Br. 2008;90:1291–7.
10. Hart AJ, Ilo K, Underwood R, Cann P, Henckel J, Lewis A, et al. The relationship between the angle of version and rate of wear of retrieved metal-on-metal resurfacings: a prospective CT-based study. J Bone Joint Surg Br. 2011;93:315–20.
11. Langton DJ, Jameson SS, Joyce TJ, Webb J, Nargol AVF. The effect of component size and orientation on the concentrations of metal ions after resurfacing arthroplasty of the hip. J Bone Joint Surg Br. 2008;90:1143–51.
12. Hart AJ, Sabah SA, Bandi AS, Maggiore P, Tarassoli P, Sampson B, et al. Sensitivity and specificity of blood cobalt and chromium metal ions for predicting failure of metal-on-metal hip replacement. J Bone Joint Surg Br. 2011;93:1308–13.
13. Johnson D, Reaction A, Debris M, Espa LS, Espa R. Documento de información y asesoramiento. Actuación ante pacientes portadores de prótesis total de cadera con par de fricción metal-metal. Sociedad Española de Cirugía de Cadera (SECCA); 2010. p. 1–12. Available froom: https://www.secca.es/documentos/guias/protesisMoMclinguide2012.pdf
14. Smith AJ, Dieppe P, Howard PW, Blom AW. Failure rates of metal-on-metal hip resurfacings: analysis of data from the National Joint Registry for England and Wales. Lancet. 2012;380:1759–66.
15. Kuzyk PRT, Sellan M, Olsen M, Schemitsch EH. Hip resurfacing versus metal-on-metal total hip arthroplasty – are metal ion levels different? Bull NYU Hosp Jt Dis. 2011;69 Suppl. 1:S5–11.
16. Bernstein M, Gupta S, Petit A, Zukor DJ, Huk OL, Antoniou J. The effect of operative factors on outlier ion levels in patients with metal-on-metal hip arthroplasties. Bull NYU Hosp Jt Dis. 2011;69 Suppl. 1:S20–6.
17. Emmanuel AR, Bergin KM, Kelly GE, McCoy GF, Wozniak AP, Quinlan JF. The effect of acetabular inclination on metal ion levels following metal-on-metal hip arthroplasty. J Arthroplasty. 2014;29:186–91.
18. Mann SM, Kunz M, Ellis RE, Rudan JF. Component position and metal ion levels in computer-navigated hip resurfacing arthroplasty. J Arthroplasty. 2017;32:119–24.
19. Hart AJ, Muirhead-Allwood S, Porter M, Matthies A, Ilo K, Maggiore P, et al. Which factors determine the wear rate of large-diameter metal-on-metal hip replacements? Multivariate

analysis of two hundred and seventy-six components. J Bone Joint Surg Am. 2013;95:678–85.
20. Daniel J, Ziaee H, Pradhan C, McMinn DJW. Systemic metal exposure in large- and small-diameter metal-on-metal total hip replacements. Orthopedics. 2008;31 Suppl 2: orthosupersite.com/view.asp?rID=37189.
21. Bernstein M, Walsh A, Petit A, Zukor DJ, Huk OL, Antoniou J. Femoral head size does not affect ion values in metal-on-metal total hips. Clin Orthop Relat Res. 2011;469: 1642–50.
22. Smith J, Lee D, Bali K, Railton P, Kinniburgh D, Faris P, et al. Does bearing size influence metal ion levels in large-head metal-on-metal total hip arthroplasty? A comparison of three total hip systems. J Orthop Surg Res. 2014;9:3.
23. Hernández-Vaquero D, García-Pascual M, Iglesias-Fernández S, Escandon-Rodríguez A. Metal-on-metal surface hip arthroplasties. Is annual monitoring of blood metal levels necessary? Rev Esp Cir Ortop Traumatol. 2018;62:436–41.