

Large variation in timing of follow-up visits after hip replacement: a review of the literature

Mattia Loppini^{1,2,5}, Francesco Manlio Gambaro¹, Rob G H H Nelissen^{3,4} and Guido Grappiolo^{2,5}

¹Department of Biomedical Sciences, Humanitas University, Pieve Emanuele, Milan, Italy

²IRCCS Humanitas Research Hospital, Rozzano, Milan, Italy

³Landelijke Registratie Orthopedische Implantaten (Dutch Arthroplasty Register), 's Hertogenbosch, The Netherlands

⁴Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

⁵Fondazione Livio Sciuotto Onlus, Campus Savona – Università degli Studi di Genova, Savona, Italy

Correspondence should be addressed to M Loppini

Email
mattia.loppini@hunimed.eu

- The study investigated the existing guidelines on the quality and frequency of the follow-up visits after total hip replacement surgery and assessed the level of evidence of these recommendations.
- The review process was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Additional works were retrieved by direct investigation of the available guidelines of the most important orthopedic societies and regulatory agencies.
- The current systematic review of the literature resulted in zero original papers, four guidelines for routine follow-up and three guidelines for special cases. Concerning the quality of evidence behind them, these guidelines were not evidence based but drafted from expert consensus.
- The most important finding of this review is the large variation of recommendations in the follow-up schedule after total hip arthroplasty and the lack of evidence-based indications. Indeed, all the above-reported guidelines are the result of a consensus among experts in the field (level of recommendation class D ‘very low’) and not based on clinical studies.

Keywords

- ▶ total hip arthroplasty
- ▶ follow-up

EFORT Open Reviews
(2022) 7, 200–205

Introduction

Total hip arthroplasty (THA) is one of the most frequent and successful surgeries performed in the orthopedic field, nevertheless, a clear consensus on post-surgical management still lacks (1). The need to define a clear protocol to manage patients after THA stems from a number of reasons such as the early identification of complications and the assessment of the right timing for a possible revision surgery. The latter aspect ensues due to the fact that prosthetic hip implants have a limited lifespan, which a recent review by Evans *et al.* has estimated to be around 20 years for 75% of patients and 25 years for 56% (2).

The gap of knowledge that the present review attempts to fill resides in the lack of clear indications regarding the follow-up visits schedule after THA. Indeed, this heterogeneity in terms of timing, number and nature of the visits following the discharge from the hospital still nowadays is not aligned with clear, evidence-based indications (3).

The main aim of the follow-up visits is to detect the asymptomatic failure of the hip prosthesis. The diagnosis

of asymptomatic failure can prevent extensive surgery such as the full revision of the acetabular component instead of the liner exchange to manage the wear and complications such as periprosthetic fractures due to severe bone reabsorption and/or gross loosening. If the THA failure presents symptomatically, the patient either self-refers (45%) or is referred by the general practitioner (19%) or is referred from other hospitals (16%) or from the emergency room (7.5%) (4). On the other hand, only routine follow-up is able to identify the asymptomatic failures and these account for 9% of the total amount of failures (5). According to these data, the vast majority of current revisions are late surgeries. However, early THA revision surgeries (e.g. only revision of a worn-down liner) can provide better outcomes with lower complication rates because they can be a less extensive and non-acute procedure. In fact, complex revisions of THA have been found to cost up to 1.5 times more than the hospital and physician resources of routine revisions (5). Another reason behind performing routine follow-up is that the

latter is able to identify not only asymptomatic failure but also slightly symptomatic patients, which symptoms are often not promptly correlated with the prosthetic implant. In addition, the traditional follow-up with scheduled outpatient visits represents an issue not only from the cost-effectiveness point of view but also for patient compliance. Indeed, only 61% of patients show up at follow-up visits at 1 year after surgery and that number drops even more at 2 years reaching 36% (6). This balance between the need to identify asymptomatic (radiographic) failures of THA (i.e. preventing more extensive revision surgery) and a cost-effective medical practice results in a vast heterogeneity regarding the proper schedule of follow-up visits after THA.

Materials and methods

The review process was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (flow chart in Fig. 1) (7). Literature research was carried out by two independent authors (M L and F M G) through August 2020 on PubMed, Google Scholar and Scopus databases with the following Medical Subject Headings: follow-up and total hip replacement. Additional information was retrieved from most recent publicly available guidelines of orthopedic societies and regulatory agencies such as the Food and

Drug Administration (FDA), the Arthroplasty Society of Australia (ASA), Scientific Committee on Emerging and Newly Identified Health Risk (SCENIHR), British Orthopedic Association (BOA), Medicines and Healthcare Products Regulatory Agency (MHRA) and the National Institute of Health 1997 (NIH), Netherlands Orthopaedic Association 2018, American Association of Hip and Knee Surgeons (AAHKS) 2019 and the American Academy of Orthopedic Surgeons 2017 (AAOS). In order to judge the relevance of a study, the following inclusion criteria were adopted: information from original papers, an orthopedic society guideline or a regulatory agency recommendation, the inclusion of information on duration and frequency of the follow-up visits after THA and information in either English, German or Italian language. As the systematic review of the literature did not find any original paper, no quantitative or qualitative assessment could be performed. Therefore, only a qualitative analysis of guidelines retrieved from orthopedic societies and regulatory agencies' websites was carried out. The latter was performed by means of the Grading of Recommendations Assessment, Development and Evaluation (GRADE).

Results

The current systematic review of the literature resulted in zero original papers, four guidelines for routine follow-up (8, 9, 10, 11) and three guidelines for special cases such as metal-on-metal (MoM) THA or small head size (5, 12, 13). Concerning the quality of evidence behind them, these guidelines were not evidence based but drafted from expert consensus. Therefore, the level of recommendation according to GRADE was of Class D (i.e. 'very low') (14).

Definition and content of follow-up

The typical surveillance program for THA includes follow-up visits composed of an interview with an orthopedic surgeon that performs a clinical assessment and, by means of an imaging tool, also a radiological assessment.

The inclusion of radiographic imaging during a routine follow-up visit after THA has been a matter of debate since it adds cost to the surveillance program. On one side, since the use of patient-reported outcomes alone is not able to assess a hip prosthesis state during a routine follow-up visit, the hip X-ray is suggested (15). On the other side, concerns on the ability of conventional radiographic imaging to effectively recognize THA failure have been raised (16). But even if plain radiography has some intrinsic limitations for the diagnosis of THA failure, it remains the first-step imaging technique and when inconclusive or doubtful, it can be followed by a more accurate tool such as a CT scan (17).

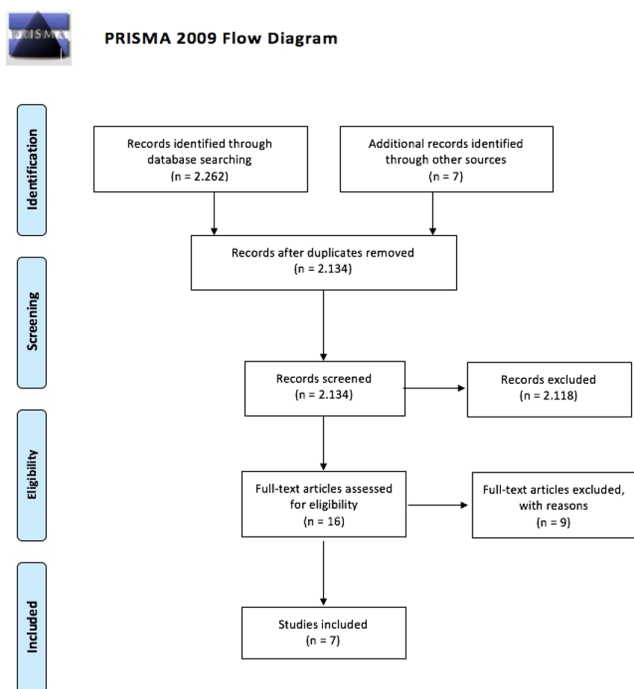


Figure 1 PRISMA chart flow depicting the studies inclusion process after careful literature review.

A further aspect to be acknowledged concerns the first visit after a THA procedure, since some guidelines (11) define the latter as the first meeting between the patient and the surgeon after the procedure typically occurring after a few weeks when the wound check and a general assessment are performed. Whereas other guidelines (9, 10) do not include this meeting as part of the follow-up schedule.

Current guidelines for routine follow-up

The systematic review of the literature and the content of orthopedic societies websites demonstrated only five clearly described recommended schedules of THA follow-up visits. Large variability on the recommendation for frequency and duration of follow-up is present (Table 1). For that matter, some guidelines only state that regular follow-up visits are important but do not specify frequency and duration during follow-up: the NIH consensus 1997 (18) and the AAOS guidelines 2017 (19).

Furthermore, three orthopedic societies recommend a follow-up schedule based on a first visit within the first year after the operation, followed by a second visit around the seventh year and then a visit every 3–5 years. These recommendations are from the BOA guidelines 2012 (10), the Netherlands Orthopaedic Association 2018 (9) and the Arthroplasty Society of Australia 2019 (8). The guidelines of the BOA are justified since the majority of revision occurs 7 years after the first implant and early detection of aseptic loosening may prevent periprosthetic fracture. The latter has increased mortality and costs associated with revision surgery in an acute situation (20). Instead, the Netherlands Orthopaedic Association guidelines present a similar rationale behind their schedule of follow-up by underlining the risk of missing asymptomatic silent osteolysis or loss of function, which increases the risk of periprosthetic fracture after an in-house fall with devastating consequences. Finally, the Arthroplasty Society of Australia gives a similar justification of their recommendation warning orthopedic surgeons to be aware that despite most aseptic loosening being symptomatic, some may present with an insidious development, hence the need for a clinical and radiological review of all THA in an

attempt to identify these ‘silent problems’ allows timely intervention.

The AAHKS 2019 (11) suggests a similar protocol compared to the three mentioned above, with a further recommended visit at the fifth year from surgery.

Current guidelines for follow-up in special cases

In some guidelines, a general schedule of follow-up visits (both frequency and duration) is missing, although precise recommendations on radiographic follow-up exist for high-risk patients (Table 2). This risk assessment is based on both patient-specific and implant-specific factors.

For example, the FDA guidelines (21) suggest regular follow-up visits (i.e. every 1–2 years) for MoM hip implants with certain risk factors (i.e. bilateral implants, the presence of small femoral heads (≤ 44 mm), female sex, patients receiving high doses of corticosteroids, with evidence of renal insufficiency, with immunosuppression, with suboptimal alignment of device components, with suspected metal sensitivity, BMI >40 and patients with high levels of physical activity).

While SCENIHR in 2014 (12) has released a statement suggesting yearly follow-up visits for all patients with MoM prostheses, small femoral head size and female gender, in addition, it recommends performing blood cobalt measurements (normal value range 2–7 $\mu\text{g/L}$) at follow-up visits.

In the United Kingdom, the annual report of MHRA 2017 (13) recommends the need for a more stringent follow-up schedule for MoM implants, younger patients and more active patients. Even more, for these patients, it is recommended to have an annual follow-up for the first 5 years then every 2 years until the tenth year and every 3 years thereafter.

As per the ASA guidelines (8), high-risk patients are defined as all patients with newly designed implants with limited long-term clinical results, younger patients, those with MoM articulation and total hip implants with small head sizes (≤ 36 mm) (22). For these patients, follow-up is recommended at yearly intervals with radiographs.

As for the latter, concerning new prosthetic implants, most guidelines also suggest a more stringent schedule of follow-up visits.: the BOA also recommends yearly

Table 1 Current guidelines for routine follow-up after THA.

| Source | 1st visit | 2nd visit | 3rd visit | 4th visit | 5th visit | 6th visit | 7th visit |
|-----------------|-----------|------------|-----------------|---------------|-----------|-----------|------------|
| AAHKS 2019 (11) | 2–3 weeks | 6 weeks | 3–6 months | 1 year | 5 years | 10 years | Every year |
| AOA 2006 (38) | 3 months | 1–2 years | 10 years | Every 2 years | | | |
| ASA 2019 (8) | 1–2 years | 7–10 years | Every 3–5 years | | | | |
| BOA 2012 (10) | <1 years | 7 years | Every 3 years | | | | |
| NOA 2018 (9) | 6 weeks | 12 weeks | 5 years | | | | |

AAHKS, American Association of Hip and Knee Surgeons; AOA, Australian orthopaedic association; ASA, Arthroplasty Society of Australia; BOA, British orthopedic association; NOA, Netherlands Orthopedic Association.

Table 2 Distribution of patient- and implant-specific factors in the current guidelines.

| | FDA (21) | ASA 2019 (8) | SCENIHR (12) | BOA 2012 (10) | MHRA 2017 (13) |
|--------------------------|----------|--------------|--------------|---------------|----------------|
| Patient-specific factors | | | | | |
| Young | | x | | | x |
| Female sex | x | | x | | |
| Obesity | x | | | | |
| Sport | x | | | | x |
| Corticosteroids | x | | | | |
| CKD | x | | | | |
| Immunosuppression | x | | | | |
| Metal sensitivity | x | | | | |
| Implant-specific factors | | | | | |
| Metal-on-Metal | x | x | x | | x |
| New prosthesis | | x | | x | |
| Small head size | x | x | x | | |

ASA, Arthroplasty Society of Australia; BOA, British Orthopedic Association; CKD, chronic kidney disease; FDA, Food and Drug Administration; MHRA, Medicines and Healthcare Products Regulatory Agency; SCENIHR, Scientific Committee on Emerging and Newly Identified Health Risk.

radiographic follow-ups until the fifth year then every 2 years until the tenth year and then every 3 years.

Discussion

The most important finding of this review is the large variation of recommendations on the follow-up schedule after THA as well as the lack of evidence-based recommendations of these follow-ups. Although, all reported guidelines are the result of a consensus among experts in the field (level of recommendation class D ‘very low’) with a rationale on the recommendation but not based on evidence from clinical studies.

Current guidelines do not recommend more than one follow-up visit (including radiographs) within the first year and one follow-up visit (including radiographs) between 2 and 10 years after surgery. Nevertheless, the assessment of a temporal sequence of radiographs plays a critical role in the early (asymptomatic) detection of failure of an implant. Although the pathophysiology of aseptic loosening is not completely understood, the main underlying mechanism is represented at radiographs by periprosthetic osteolysis induced by implant particles (e.g. liner wear). The latter usually have a diameter ranging from 0.2 to 10 µm (23), which induces an inflammatory process involving a variety of cells, eventually leading to aseptic loosening of the implant. This process results in visible radiological signs that the trained orthopedic surgeon can promptly identify at a radiograph. The identification of these radiological signs is facilitated when a temporal sequence of radiographs of the patient (e.g. hip etc) are present. Hence, the need of performing a schedule of regular follow-ups including radiological imaging is needed to detect subtle radiological changes. In particular, the temporal sequence of radiographs is most important during the first 2 years

after hip prosthesis implantation, since most implant migration occurs in this time window (24). This concept is supported by Mjöberg who in his ‘theory of early loosening of hip prosthesis’ states that loosening is likely to begin at an early stage due to either insufficient initial fixation or an early loss of fixation (25). It should be noted that migration at radiographs is measured with an (in) accuracy of 4–12 mm. For that matter, radiostereometric analysis (RSA) is a highly accurate method to determine migration and wear of the prosthetic implant, with an accuracy of 0.1 mm in three dimensions (26, 27). The advantage of the highly accurate RSA technique is that implants which are at risk for late failure can be detected within 1–2 years of follow-up (28, 29, 30). Data from these RSA studies on prosthesis migration within the first 2 years may support performing sequential radiographs during this time window, in order to detect early aseptic loosening. Nevertheless, further studies evaluating evidence of the use of normal radiographs, preferably using machine learning algorithms, are needed to support the importance of sequential series of hip radiographies for early detection of implant fixation problems.

Another interesting finding of this review is that a more stringent follow-up was recommended in high-risk patients, although each guideline defined ‘high-risk’ patients differently, making comparison difficult. The latter may be responsible for some of the large variation on the recommendation of follow-up visits after THA. Patient-related variables which determine to some extent timing of follow-up visits are younger age, female sex and high activity sport level. Indeed, according to the ASA and MHRA guidelines (8, 13), younger patients require a more stringent follow-up, consisting of a yearly visit. While implant-specific variables which are associated with the timing of follow-up are the use of MoM prosthesis, the use of new prosthesis and the small size of the femoral head.

The large variation of recommendations in the follow-up schedule after THA observed by the current study is reflected by the lack of recommendations among the most relevant worldwide regulatory agencies in the medical field. Indeed FDA (21), the European Medicines Agencies (31) and the National Institute of Health and Care Excellence (32) only stress the importance of follow-up after THA without specifying its exact duration and frequency.

In addition, the frequency of follow-ups after a THA intervention is a matter that concerns the medical area as well as the socio-economic one. Indeed, in order to improve the efficiency of national healthcare systems, a cost-effectiveness analysis strictly depends on regional, economic and social aspects (33) therefore contributing to the heterogeneity observed in the current study.

Already in late 90’, an attempt was made to improve the cost-effectiveness of the radiographic follow-up

visits for patients who had hip replacement surgery. It was theorized that a system in which trained medical staff would review routine radiographs in order to decide if a face-to-face visit was needed. This system would have allocated outpatient follow-up visits only to patients at risk of THA failure. More recently, this concept has been further developed in what has been defined as the ‘virtual clinic’. This system determines who should be offered a face-to-face appointment based on routine radiographs and questionnaires (Oxford hip or knee score), reviewed by a consultant orthopedic surgeon (34).

To investigate the efficacy of the virtual clinic to detect potential implant failure, a recent study compared the traditional outpatient visits with radiographs and questionnaires related to revision symptoms without patient contact. The results showed a substantial agreement between the two, especially for TKA (81%) and to a lower extent also for THA (69%) suggesting that the virtual clinic is a valid alternative to face-to-face visits (35). A similar study that randomized THA patients to either the traditional follow-up system based on routine outpatient visits (including radiographs) or to a questionnaire- and radiograph-based remote follow-up found that no patients who had a potential failure were missed by the remote follow-up (36). Recently during the coronavirus disease 2019 pandemic, some surgeons of BOA employed virtual follow-ups by using telephone consultations for patients unable to attend their routine THA postoperative visits. Although 63% of patients were satisfied by the ‘virtual’ appointment, 75% of patients would prefer to have their next appointments face-to-face. The latter may be related to the population of 70 years and older and the unfamiliarity with technology like electronic questionnaires. Although this may also be related to accessibility and internet density, which can be different between countries (37), it could not be related to the confidence a physical examination and face-to-face explanation give to a patient. The latter also stresses the importance of general guidelines which have to be patient specific. The main limitations of this review are represented by the limited number of guidelines and no clinical studies which report on the topic of recommendation of radiographic follow-up and the ambiguity of the definition of post-surgical follow-up. For that matter, most guidelines do not include the first visit after surgery as part of the schedule of visits, which is in our opinion important in order to compare subsequent future radiographs. Another limitation stems from the study design of the current review. In fact, after performing a systematic review of the literature and retrieving zero original papers, we could only analyze guidelines from orthopedic societies and regulatory agencies.

Conclusions

- The follow-up schedule after THA is nowadays arbitrary organized based on consensus among experts and not on evidence.
- Current guidelines do not recommend more than two radiographs 10 years after surgery.
- In certain guidelines, more stringent follow-up was recommended in high-risk patients, but the definition of ‘high risk’ was very heterogeneous among them.
- There is a clear need to develop data-based recommendations for clinical and radiographic follow-up after hip replacement.

ICMJE Conflict of Interest Statement

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

Funding Statement

This work did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector.

References

1. **Varacallo M, Luo TD & Johanson NA.** Total hip arthroplasty (THA) techniques. In *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing, 2020 [cited 2020 Aug 27]. (available at: <http://www.ncbi.nlm.nih.gov/books/NBK507864/>)
2. **Evans JT, Evans JP, Walker RW, Blom AW, Whitehouse MR & Sayers A.** How long does a hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. *Lancet* 2019 **393** 647–654. ([https://doi.org/10.1016/S0140-6736\(18\)31665-9](https://doi.org/10.1016/S0140-6736(18)31665-9))
3. **Veysi VT, Jones S, Stone MH & Limb D.** Out-patient follow-up after total hip replacement in one health region. *Journal of the Royal College of Surgeons of Edinburgh* 1998 **43** 95–96.
4. **Cassidy RS, hEireamhoin SO & Beverland DE.** Guidelines for the follow-up of total hip arthroplasty: do they need to be revised? *Bone and Joint Journal* 2019 **101-B** 536–539. (<https://doi.org/10.1302/0301-620X.101B5.BJJ-2018-0853.R2>)
5. **Hendricks TJ, Chong ACM & Cusick RP.** The cost of routine follow-up in total joint arthroplasty and the influence of these visits on treatment plans. *Kansas Journal of Medicine* 2018 **11** 59–66. (<https://doi.org/10.17161/kjm.v11i3.8692>)
6. **Clohisy JC, Kamath GV, Byrd GD, Steger-May K & Wright RW.** Patient compliance with clinical follow-up after total joint arthroplasty. *Journal of Bone and Joint Surgery: American Volume* 2008 **90** 1848–1854. (<https://doi.org/10.2106/JBJS.G.00856>)
7. **Kendall C, Maskalyk J & Palepu A.** Closing open medicine. *Open Medicine* 2014 **8** e147–e149.
8. **Broughton N, Lovelock T, Steiger RD, Page R, Donnelly B, Solomon M, Collopy D & McMahon S.** 2019 Guidelines for long term follow-up of joint replacement patients. (available at: https://aoa.org.au/docs/default-source/advocacy/2019-asa-guidelines-for-long-term-follow-up-of-joint-replacement-patients.pdf?sfvrsn=c9bac204_10)
9. draft-guideline-total-hip-prosthesis.pdf [Internet] [cited 2020 Aug 27]. (available at: <https://www.orthopeden.org/downloads/502/draft-guideline-total-hip-prosthesis.pdf>)

10. Blue Book. 2012 fsh nov 2012.pdf [Internet]. [cited 2020 Aug 27]. (available at: <https://www.britishhipociety.com/uploaded/Blue%20Book%202012%20fsh%20nov%202012>)
11. Follow up | hip and knee care [Internet]. AAHKS Hip and Knee Care. [cited 2020 Aug 27]. (available at: <https://hipknee.aahks.org/dont-take-your-new-joint-for-granted-follow-up-care/>)
12. European Commission, Directorate General for Health & Consumers. *Opinion on the Safety of Metal-On-Metal Joint Replacements with a Particular Focus on Hip Implants*. [Internet]. Luxembourg: European Commission, 2014 [cited 2020 Aug 27]. (available at: <http://dx.publications.europa.eu/10.2772/76284>)
13. Great Britain, Medicines and Healthcare Products Regulatory Agency, Hudson I & Rawlins M. *Medicines and Healthcare Products Regulatory Agency Annual Report and Accounts 2016/17*. London: HM Government, 2017.
14. EBM: levels of evidence – essential evidence plus [Internet]. [cited 2020 Nov 26]. (available at: https://www.essentialevidenceplus.com/product/ebm_loe.cfm?show=grade#accept)
15. Smith LK, Cramp F, Palmer S, Coghil N & Spencer RF. Empirical support for radiographic review: a follow-up study of total hip arthroplasty. *Hip International* 2013 **23** 80–86. (<https://doi.org/10.5301/HIP.2012.9912>) (available at: <https://journals.sagepub.com/doi/10.5301/HIP.2012.9912>)
16. Safir O, Lin C, Kosashvili Y, Mayne IP, Gross AE & Backstein D. Limitations of conventional radiographs in the assessment of acetabular defects following total hip arthroplasty. *Canadian Journal of Surgery* 2012 **55** 401–407. (<https://doi.org/10.1503/cjs.000511>)
17. Blum A, Gondim-Teixeira P, Gabiache E, Roche O, Sirveaux F, Olivier P, Coudane H, Nancy Association for Prosthesis Exploration (NAPE), Raymond A, Louis M, et al. Developments in imaging methods used in hip arthroplasty: a diagnostic algorithm. *Diagnostic and Interventional Imaging* 2016 **97** 735–747. (<https://doi.org/10.1016/j.diii.2016.07.001>)
18. The National Institutes of Health (NIH) consensus development program: total hip replacement [Internet]. [cited 2020 Aug 27]. (available at: (<https://consensus.nih.gov/1994/1994hipreplacement098html.htm>))
19. management-of-osteoarthritis-of-the-hip-companion-consensus-statements_3.13.17.pdf [Internet]. [cited 2020 Aug 27]. (available at: https://aaos.org/globalassets/quality-and-practice-resources/osteoarthritis-of-the-hip/management-of-osteoarthritis-of-the-hip-companion-consensus-statements_3.13.17.pdf)
20. Vanhegan IS, Malik AK, Jayakumar P, UI Islam S & Haddad FS. A financial analysis of revision hip arthroplasty: the economic burden in relation to the national tariff. *Journal of Bone and Joint Surgery: British Volume* 2012 **94** 619–623. (<https://doi.org/10.1302/0301-620X.94B5.27073>)
21. Health C for D and R. *Information for Orthopaedic Surgeons* [Internet]. FDA, 2019. [cited 2020 Aug 27]. (available at: <https://www.fda.gov/medical-devices/metal-metal-hip-implants/information-orthopaedic-surgeons>)
22. Loppini M & Grappiolo G. Uncemented short stems in primary total hip arthroplasty: the state of the art. *EFORT Open Reviews* 2018 **3** 149–159. (<https://doi.org/10.1302/2058-5241.3.170052>)
23. Abu-Amer Y, Darwech I & Clohisy JC. Aseptic loosening of total joint replacements: mechanisms underlying osteolysis and potential therapies. *Arthritis Research and Therapy* 2007 **9** (Supplement 1) S6. (<https://doi.org/10.1186/ar2170>)
24. Mjöberg B. Loosening of the cemented hip prosthesis. The importance of heat injury. *Acta Orthopaedica Scandinavica: Supplementum* 1986 **221** 1–40.
25. Mjöberg B. The theory of early loosening of hip prostheses. *Orthopedics* 1997 **20** 1169–1175. (<https://doi.org/10.3928/0147-7447-19971201-12>)
26. Bottner F, Su E, Nestor B, Azzis B, Sculco TP & Bostrom M. Radiostereometric analysis: the hip. *HSS Journal* 2005 **1** 94–99. (<https://doi.org/10.1007/s11420-005-0114-2>)
27. Nelissen RGHH, Pijls BG, Kärrholm J, Malchau H, Nieuwenhuijse MJ & Valstar ER. RSA and registries: the quest for phased introduction of new implants. *Journal of Bone and Joint Surgery: American Volume* 2011 **93** (Supplement 3) 62–65. (<https://doi.org/10.2106/JBJS.K.00907>)
28. Wolf O, Mattsson P, Milbrink J, Larsson S & Mallmin H. Periprosthetic bone mineral density and fixation of the uncemented CLS stem related to different weight bearing regimes: a randomized study using DXA and RSA in 38 patients followed for 5 years. *Acta Orthopaedica* 2010 **81** 286–291. (<https://doi.org/10.3109/17453674.2010.487238>)
29. van der Voort P, Pijls BG, Nieuwenhuijse MJ, Jasper J, Fiocco M, Plevier JWM, Middeldorp S, Valstar ER & Nelissen RG. Early subsidence of shape-closed hip arthroplasty stems is associated with late revision. A systematic review and meta-analysis of 24 RSA studies and 56 survival studies. *Acta Orthopaedica* 2015 **86** 575–585. (<https://doi.org/10.3109/17453674.2015.1043832>)
30. Pijls BG, Valstar ER, Nouta KA, Plevier JW, Fiocco M, Middeldorp S & Nelissen RG. Early migration of tibial components is associated with late revision: a systematic review and meta-analysis of 21,000 knee arthroplasties. *Acta Orthopaedica* 2012 **83** 614–624. (<https://doi.org/10.3109/17453674.2012.747052>)
31. draft-guideline-safety-efficacy-follow-risk-management-advanced-therapy-medicinal-products-revision_en.pdf [Internet]. [cited 2020 Nov 26]. (available at: https://www.ema.europa.eu/en/documents/scientific-guideline/draft-guideline-safety-efficacy-follow-risk-management-advanced-therapy-medicinal-products-revision_en.pdf)
32. National Guideline Centre (UK). *Evidence Review for Long-Term Follow-Up and Monitoring: Joint Replacement (Primary): Hip, Knee and Shoulder: Evidence Review T* [Internet]. London (UK): National Institute for Health and Care Excellence, 2020. [cited 2020 Nov 26]. (available at: <http://www.ncbi.nlm.nih.gov/books/NBK561393/>)
33. Wei W, Ulyte A, Gruebner O, von Wyl V, Dressel H, Brünger B, Blozik E, Bähler C, Braun J & Schwenkglens M. Degree of regional variation and effects of health insurance-related factors on the utilization of 24 diverse healthcare services – a cross-sectional study. *BMC Health Services Research* 2020 **20** 1091. (<https://doi.org/10.1186/s12913-020-05930-y>)
34. Lovelock T, O'Brien M, Young I & Broughton N. Two and a half years on: data and experiences establishing a 'virtual clinic' for joint replacement follow up. *ANZ Journal of Surgery* 2018 **88** 707–712. (<https://doi.org/10.1111/ans.14752>)
35. Kingsbury SR, Dube B, Thomas CM, Conaghan PG & Stone MH. Is a questionnaire and radiograph-based follow-up model for patients with primary hip and knee arthroplasty a viable alternative to traditional regular outpatient follow-up clinic? *Bone and Joint Journal* 2016 **98-B** 201–208. (<https://doi.org/10.1302/0301-620X.98B2.36424>)
36. Marsh JD, Bryant DM, MacDonald SJ, Naudie DDR, McCalden RW, Howard JL, Bourne RB & McAuley JP. Feasibility, effectiveness and costs associated with a web-based follow-up assessment following total joint arthroplasty. *Journal of Arthroplasty* 2014 **29** 1723–1728. (<https://doi.org/10.1016/j.arth.2014.04.003>)
37. BOA. Virtual follow-up for first appointment after hip and knee arthroplasty surgery is acceptable during the COVID-19 pandemic but not for routine practice [Internet]. [cited 2020 Nov 26]. (available at: <https://www.boa.ac.uk/policy-engagement/journal-of-trauma-orthopaedics/journal-of-trauma-orthopaedics-and-coronavirus/virtual-follow-up-for-first-appointment-after-hip.html>)
38. Australian Orthopaedic Association 2006 National joint replacement registry Annual report 2006 Hip and knee replacement from September 1999 to December 2005. (available at: <https://aoanjrr.sahmri.com/documents/10180/75132/Annual+Report+2006>)