Orthopaedics & Traumatology: Surgery & Research 105 (2019) 383–388

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Original article

Bone cement usage modalities at a multi-site university hospital centre

Marine Barral[a], Laure Lalande[a], Anthony Viste[b,c], Jean-Luc Besse[b,c], Michel-Henri Fessy[b,c], Emmanuelle Carre[a,*]

[a] Service de Pharmacie, Hospices Civils de Lyon, Centre Hospitalier Lyon-Sud, 165, chemin du Grand Revoyet, 69495 Pierre-Bénite cedex, France
[b] Service de Chirurgie Orthopédique et Traumatologique, Hospices Civils de Lyon, Centre Hospitalier Lyon-Sud, 165, chemin du Grand Revoyet, 69495 Pierre-Bénite cedex, France
[c] Laboratoire de Biomécanique et Mécanique des Chocs, Université Lyon 1, IFSTTAR, LBMC UMR-T 9406, 69675 Bron cedex, France

ARTICLE INFO

Article history:
Received 27 June 2018
Accepted 19 November 2018

Keywords:
Bone cement
Survey
Cementing technique
Guidelines

ABSTRACT

Background: Although cements are widely used during arthroplasty procedures, few recommendations exist regarding their optimal usage modalities, which, nevertheless, govern the long-term surgical outcomes. No detailed information is available on how cements are used in French hospitals. The objectives of this questionnaire survey among surgeons working at a multi-site university hospital in France were to describe practices, determine whether these varied with surgeon experience, and look for differences compared to recommendations.
Hypothesis: Cementing techniques vary widely among surgeons at a university hospital.
Material and methods: A questionnaire was sent to the five orthopaedic departments of our university hospital to collect data on the surgeons (age, sex, years of experience), their practice (type of implants used, annual number of arthroplasties with each arthroplasty type and each indication, and proportion of cemented arthroplasties), the type of cement used, and the cementing technique.
Results: Of the 34 surgeons, 21 completed the questionnaire, 20 males and 1 female with a mean age of 41 years (range, 31–59 years) and a mean of 11 years (range, 1–29 years) of experience. High-viscosity antibiotic-loaded cement was preferred by 20 (95%) surgeons, notably for knee arthroplasties, of which the median annual numbers were 55 (range, 0–218) and 8 (range, 1–40) for primary and revision cemented procedures, respectively. Various cementing techniques in ambient air were used: 12/21 (57%) surgeons used pulsed lavage to prepare the bone before cementation and 18/21 (86%) applied the cement to both the bone cuts and the implant. Of the 18 surgeons who performed knee arthroplasties, 12 used pulsed lavage, including 9 of the 11 surgeons with more than 5 years of experience and only 3 of the 7 less experienced surgeons. Similarly, of the 12 surgeons who used pulsed lavage for cemented arthroplasties, 11 were among the 12 surgeons who performed more than 15 cemented arthroplasties annually and 1 was among the 6 who performed fewer cemented arthroplasties.
Discussion: Cementing techniques varied widely, reflecting the dearth of recommendations and controversial results of published studies. In our centre, the use of pulsed lavage to improve bone preparation and cement application to both the bone and the implant should be promoted, as both techniques are universally advocated. Our study demonstrates the need to provide surgeons with opportunities to exchange their experiences about the other aspects of cementing in order to harmonise practices and to optimise the use of cement.
Level of evidence: IV, questionnaire survey.

1. Introduction

Polymer bone cements have been used in orthopaedic surgery for many years. Nevertheless, no consensus exists regarding the best methods for using bone cements, and various preparation and application techniques have been described [1,2]. These elements are essential since the type of cement used and cementing

* Corresponding author. Service de Pharmacie, Hospices Civils de Lyon, Centre Hospitalier Lyon-Sud, 165, chemin du Grand Revoyet, 69495 Pierre-Bénite cedex, France.
E-mail address: emmanuelle.carre@chu-lyon.fr (E. Carre).

https://doi.org/10.1016/j.otsr.2018.11.022
1877-0568/

technique are known to influence the risk of aseptic loosening [2], being among the leading reasons for hip and knee arthroplasty revision (29%–45%) [3–5]. The optimal use of bone cements increases long-term arthroplasty success rate [6].

In France, orthopaedic surgeons receive little guidance about cement use during their training. Furthermore, recommendations about cementing techniques are extremely scarce. The introduction on the market of cementless prostheses, notably for the hip, does not encourage further training about cementation and may explain the limited experience of surgeons with cement preparation, preparation of bone recipient sites, and cement application techniques. Several surveys about cementing practices were performed over the last few decades in other countries [7–9], but no detailed information on cementing techniques used in French hospitals is available.

The objectives of this questionnaire survey among surgeons working in a multi-site university hospital in France were to describe practices, determine whether these varied according to surgeon experience, and highlight differences with existing recommendations. The working hypothesis was that cementing techniques varied widely among surgeons in a university hospital.

2. Material and methods

2.1. Material

The surgeons at our university hospital were asked to participate in a questionnaire survey. The questionnaire (Supplementary Data) was developed by a pharmacy resident (MB) and a hospital pharmacist (EC) in charge of implantable medical devices since 2003 then validated by a senior orthopaedic surgeon (AV). The questionnaire content was based on a review of the literature and of clinical practice guidelines about cementing techniques.

The first section of the questionnaire collected data on the respondent, including age, sex, number of years of experience, type of arthroplasties performed (hip, knee, shoulder, ankle, and/or other), annual number of each type of arthroplasty in each indication (primary arthroplasty, revision arthroplasty, or spacer), and proportion of cemented arthroplasties. The second section asked about the type or types of bone cement used and the cementing techniques in terms of cement preparation, application, and pressurisation.

2.2. Methods

The questionnaire was emailed to the heads of four adult and one paediatric orthopaedic surgery departments at our hospital. The department heads were asked to send the questionnaire to all the surgeons in their team. Respondents then returned the completed questionnaires by email. The first email was sent on 31 January 2017, a reminder was sent 1 month later, and the completed questionnaires were to be returned by 31 March 2017. Additional data were collected in 2018 to assess actual caseloads for 2017. Missing data were obtained via implant traceability.

2.3. Statistical analysis

The questionnaire data were anonymised, entered into the study database, and analysed using Excel 2010™ (Microsoft, Redmond, WA, USA). Descriptive statistics were computed.

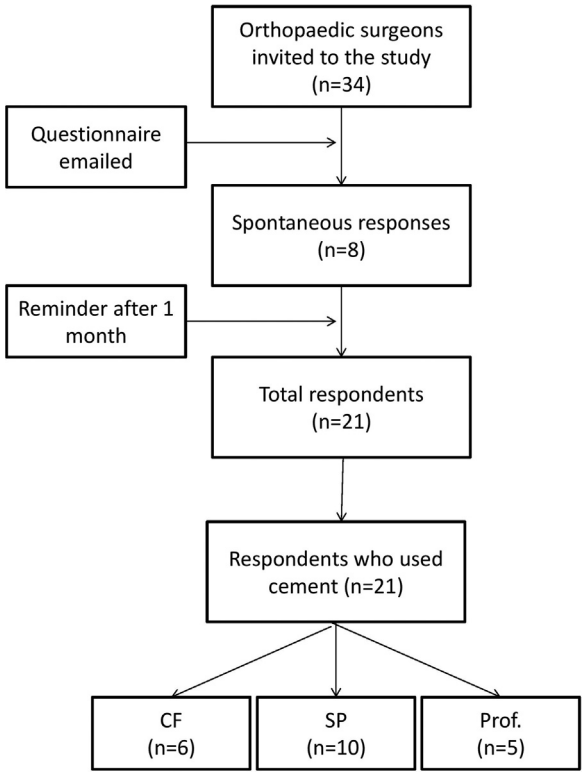

Fig. 1. Flow-chart of the study participants. Prof.: professor; SP: staff physician; CF: clinical fellow.

Table 1
Features of the respondents.

Number of respondents	21
Males, *n*	20
Age, years, mean ± SD (range)	41 ± 10 (31–59)
Job title, *n*	
Professor	5
Staff physician	10
Clinical fellow	6
Years of experience, mean ± SD (range)	11 ± 10 (1–29)

3. Results

Of the 34 orthopaedic surgeons in the hospital, 21 returned the questionnaire (Fig. 1). Table 1 lists their main features. All respondents used bone cements in their everyday practice. Of the 21 respondents, 20 were male; mean age was 41 years (range, 31–59 years) and mean years of experience in orthopaedic surgery was 11 (range, 1-29 years). Table 2 reports the annual number of arthroplasty procedures performed and the proportion of cemented arthroplasties. Bone cement was used chiefly for knee arthroplasty, with annual median numbers of 55 (range, 0–218) primary arthroplasties and 8 (range, 1–40) revision arthroplasties. Table 3 describes the cementing techniques used by the respondents. Of the 21 respondents, 20 (95%) preferred high-viscosity gentamicin-loaded cement, except for the upper limb, for which cement without antibiotics was used. All 21 respondents indicated that the main reason for using cement was implant fixation during primary or revision arthroplasty. In addition, 10/21 respondents stated that they occasionally used cement as a spacer when performing two-stage revision arthroplasty, in compliance with European Union certification of bone cements. All respondents prepared the cement in ambient air; none used vacuum systems. Pulsed lavage was used for preparation by 12/21 (57%) respondents. Of the 15 respondents who reported using a cement gun,

Table 2
Caseloads for each type of arthroplasty in 2017.

Type of arthroplasty	N of surgeons	N of arthroplasties/year/surgeon median (range)	N of cemented arthroplasties/year/surgeon median (range)	% of cemented arthroplasties median (range)
Primary THA	19	45 (1–429)	0 (0–21)	0% (0–14)
Revision THA	19	9 (1–112)	1 (0–10)	10% (0–100)
Primary TKA	18	78 (5–218)	55 (0–218)	92% (0–100)
Revision TKA	16	8 (2–40)	8 (1–40)	100% (50–100)
Primary TSA	5	7 (1–18)	2 (0–3)	43% (0–100)
Revision TSA	2	1 (0–1)	1 (0–1)	50% (0–100)
Primary TEA	1	3	3 (3–3)	100%
Revision TAA	2	27 (9–44)	2 (0–3)	3% (0–7)

THA; total hip arthroplasty; TKA; total knee arthroplasty; TSA; total shoulder arthroplasty; TEA; total elbow arthroplasty; TAA; total ankle arthroplasty.

9 used a gun only for revision total hip arthroplasty and 6 only for cementing the stems of total knee prostheses. Application of the cement to both the bone and the implant was reported by 18/21 (86%) surgeons, including the 12 surgeons who used pulsed lavage. Pressurisation was achieved manually using a gauze square, spatula, or gun at the femur during hip arthroplasty. Finally, when performing total knee arthroplasty, 10 surgeons cemented only part of the stem and 8 the entire stem. No surgeons used cement for ankle implant fixation, as only cementless ankle prostheses are available in Europe; however, cement was used after curetting of osteolytic defects and as a spacer after prosthesis removal.

For the hip and knee, the only items that differed with years of experience was the use of pulsed lavage. Of the 18 surgeons who performed knee arthroplasties, 6 did not use pulsed lavage, including 4 of the 7 surgeons with less than 5 years of experience compared to only 2 of the 11 more experienced surgeons. Similarly, among the 6 surgeons who did not use pulsed lavage, 5 were among the 6 surgeons performing fewer than 15 cemented arthroplasties per year and only 1 was among the 12 surgeons performing at least 15 cemented arthroplasties per year.

4. Discussion

This is the first survey of practices regarding the use of bone cement for orthopaedic surgery in France. We obtained information on the practices of several teams of orthopaedic surgeons working in a university hospital. Considerable variability was found in cementing practices, indicating a need for better surgeon training in the use of bone cement and for fostering exchanges with the goal of developing uniform strategies. Training is all the more essential given the paucity of clinical practice guidelines on the use of bone cement and the conflicting nature of published data on this topic.

High-viscosity gentamicin-loaded cement was used predominantly in our hospital, in keeping with reports from other countries [7–9] and in compliance with recommendations issued by the French National Authority for Health (HAS) [10]. Bone cement must be prepared by mixing its liquid and powder components. This preparation step governs the final quality of the cement and, consequently, the strength of implant fixation to bone. Vacuum devices for cement mixing are not available at our hospital and are less often used overall in France than in other countries (Table 4). The main barriers to the use of vacuum devices are cost (30 € to 50 €) and uncertainty in the literature regarding clinical benefits [11–13].

Before cementing, the recipient bone must be cleansed and dried. Abundant irrigation of the bone cuts by pulsed lavage is recommended for both hip and knee arthroplasty [14–16] and is widely used according to surveys done in other countries (Table 4). Our study demonstrates that pulsed lavage is insufficiently used in our institution and should therefore be promoted.

Various methods are used to apply and pressurise bone cement, both in our hospital and elsewhere (Table 4). Manual cement application methods include a gauze pad, finger packing, a spatula, and a syringe. Alternatively, a cement gun that applies the cement under pressure can be used [17]. The data available in the literature are not sufficient to determine which method is optimal. Manual methods may fail to ensure adequate penetration of the cement, but using a cement gun carries a theoretical risk of thermal injury and bone loss, which may be greatest during revision arthroplasty [18–20]. The cement can be applied to the bone, the implant, or both. These three techniques have been compared, notably during knee arthroplasty. Cementing both the bone and the implant may provide optimal cement penetration within bone [2,18]. Finally, pressurisation after cement application is indispensable to ensure final hardening and to prevent a drop in intramedullary pressure. Other benefits of pressurisation are improved penetration of the cement into cancellous bone and decreased cement porosity [21,22]. In the absence of clear recommendations, preference should be given to cement application on both the bone cuts and the implant components. The applications and pressurisation methods should be left at the discretion of each surgeon. In sum, cementing practices at our hospital, although heterogeneous, seem acceptable, except for insufficient use of pulsed lavage.

This study has several limitations. The data were obtained by self-report and may therefore not be fully representative of actual practices. Nevertheless, the data on caseload, types of cement used, and cement preparation methods were confirmed by checking the traceability data for the implants and cements and the list of devices available at our hospital (cement guns and vacuum mixing systems). Although the participants in our survey worked in five different departments, all these were in the same hospital and provided the same cements and ancillary devices (e.g., cement guns and mixing systems). It would be of interest to conduct a larger survey throughout a region or the entire country. The response rate was satisfactory and similar to that in surveys of bone cement usage performed in other countries [7–9,23]. In addition, most of the non-respondents were clinical fellows who had less experience and lower caseloads compared to the staff surgeons.

Table 3
Cements and cementing techniques used by each surgeon.

Site	Job title	Experience (y)	Name of cement	N cemented implants/Total primary THA, *n*/*n* (%)	N cemented implants/Total revision THA, *n*/*n* (%)	N cemented implants/Total primary TKA, *n*/*n* (%)	N cemented implants/Total revision TKA, *n*/*n* (%)	N cemented implants/Total other (TSA, TEA, TAA), *n*/*n* (%)	Pulsed lavage	Application method	Application site(s)	Pressurisation method	Tibial stem cementation
1	Prof.[b]	27	Palacos R + G	21/429 (5%)	13/115 (11%)	0	0	0	No	Gun (THA)	Bone and implant	Gauze pad	NA
1	SP	7	Palacos R + G	0/61 (0%)	0/6 (0%)	70/105 (67%)	12/12 (100%)	0	No	Gun (THA), Spatula (TKA)	Bone and implant	Spatula	Partial
1	CF	2	Palacos R + G	2/63 (3%)	3/17 (18%)	6/7 (86%)	3/3 (100%)	TSA-P, 1/1 (100%)	No	Manual	Bone and implant	Manual or gauze pad	Partial
			Refobacin LV[a]	0	0	0		0	NA	Manual	NA	NA	NA
1	SP	6	Palacos R + G	0/15 (0%)	0/6 (0%)	3/25 (12%)	7/7 (100%)	0	Yes	Manual	Bone and implant	Manual or spatula	Complete
1	CF	1	Palacos R + G	2/45 (4%)	0/10 (0%)	4/7 (57%)	3/3 (100%)	TSA-P, 3/18 (17%) TSA-R, 1/1 (100%)	No	Gun (THA) or Manual	Bone (TSA) or Bone and implant	Gauze pad	Partial
1	SP	27	Palacos R + G	0	0	0	0	TAA, 3/44 (3%)	No	Manual	Bone and implant	Manual or syringe	NA
1	CF[b]	2	Palacos R + G	0/15 (0%)	0/9 (0%)	3/13 (23%)	8/8 (100%)	0	No	Manual	Bone and implant	Spatula	Complete
			Refobacin LV[a]	0	0	0		0	NA	Manual	NA	NA	NA
2	Prof.[b]	13	Palacos R + G	0/2 (0%)	0/1 (0%)	84/86 (98%)	9/9 (100%)	TSA-P, 3/7 (43%)	Yes	Manual and/or Gun	Bone and implant	Spatula	Partial
2	Prof.[b]	11	Palacos R + G	6/195 (3%)	1/10 (10%)	218/218 (100%)	11/11 (100%)	0	Yes	Manual and/or Gun	Bone and implant	Spatula	Partial
2	CF	1	Palacos R + G	0/40 (0%)	10/20 (50%)	60/60 (100%)	40/40 (100%)	0	Yes	Manual and/or Gun	Bone and implant	Spatula	Partial
2	CF[b]	2	Palacos R + G	3/24 (13%)	0/1 (0%)	92/94 (98%)	16/16 (100%)	0	Yes	Manual and/or Gun	Bone and implant	Spatula	Partial
2	CF[b]	2	Palacos R + G	2/23 (9%)	0/9 (0%)	85/85 (100%)	7/7 (100%)	0	Yes	Manual and/or Gun	Bone and implant	Spatula	Partial
3	SP[b]	7	Palacos R + G	9/63 (14%)	6/7 (86%)	14/48 (29%)	7/14 (50%)	0	Yes	Manual and/or Gun	Bone and implant	NS	Complete
3	Prof.[b]	29	Simplex	0	0	0	0	TSA-P, 0/10 (0%) TSA-R, 0/1 (0%) TEA 3/3 (100%)	No	NS	Bone	Other	NA
3	SP	5	Palacos R + G	0/40 (0%)	1/4 (25%)	0/20 (0%)	1/2 (50%)	0	No	Manual	Implant	NS	Partial
4	Prof.	16	Palacos R + G	0/1 (0%)	2/2 (100%)	5/5 (100%)	0	TSA-P, 2/2 (100%)	No	Gun	Bone	NS	Partial
5	SP	11	Palacos LV + G Refobacin R Genta	0/137 (0%)	4/11 (36%)	168/168 (100%)	6/6 (100%)	0	Yes	Manual, Osteotome, or Gun (THA)	Bone and implant	Manual or gun (THA)	Complete
5	SP[b]	7	Refobacin R Genta	1/136 (4%)	0/7 (0%)	128/128 (100%)	8/8 (100%)	0	Yes	Manual, Osteotome, or Gun (THA)	Bone and implant	Manual or gun (THA)	Complete
5	SP	27	Refobacin R Genta	0/152 (0%)	1/10 (10%)	203/203 (100%)	15/15 (100%)	0	Yes	Manual, Osteotome, or Gun (THA)	Bone and implant	Manual or gun (THA)	Complete
5	SP[b]	11	Refobacin R Genta	0/38 (0%)	1/4 (25%)	50/71 (70%)	0	TAA, 0/9 (0%)	Yes	Manual, Osteotome, or Gun (THA)	Bone and implant	Manual or gun (THA)	Complete
5	SP[b]	29	Refobacin R Genta	0/209 (0%)	3/18 (17%)	17/165 (10%)	2/2 (100%)	0	Yes	Manual, Osteotome, or Gun (THA)	Bone and implant	Manual or gun (THA)	Complete

Prof: professor; SP: staff physician; CF: clinical fellow; TSA: total shoulder arthroplasty; P: primary; R, revision; TAA: total ankle arthroplasty; TEA: total elbow arthroplasty; NA: not applicable; NS: not specified.

[a] Refobacin low-viscosity used as a spacer for two-stage surgery.

[b] Surgeons for whom we used traceability data to assess their 2017 caseload.

Table 4
Previous questionnaire studies of cements and cementing techniques.

Authors	Phillips et al. [7]	Lutz et al. [23]	Nedungayil et al. [8]	Fischer et al. [9]	Our study
Country	UK	Australia	UK	Germany	France
Extent	National	Regional (Queensland)	National	National	Local
Date of publication	1996	2002	2006	2010	2018
Number of respondents, *n* (%)	597/1162 (62%)	110/129 (85%)	762/1620 (47%)	255/492 (52%)	21/34 (62%)
Arthroplasty types	TKA (revisions)	TKA (revisions)	THA, including 77% revisions	THA	THA, TKA, TSA, TEA and TAA (primary and revision)
Frequency of use of cement	Mean: 34.3/an Range, 20-40 for most surgeons	NS	31% of surgeons did < 30 THAs/year 27%: 30–50/year 15%: 50–70/year	In 40% of centres, > 40% of THAs/year were cemented	THA-P: 0 (*n* = 19) THA-R: 1/year (*n* = 19) TKA-P: 55/year (*n* = 18) TKA-R: 8/year (*n* = 16)
N (%) of respondents who used cement	567/597 (95%)	77/110 (70%)	568/762 (75%)	NS	21/21 (100%)
Most common used cement	Palacos R + G (59%)	NS	High-viscosity (82%), antibiotic-loaded (77%) cement Palacos R + G (59%)	Palacos R + G (52%)	High-viscosity gentamicin-loaded cement (95%)
Vacuum system to mix the cement	NS	NS	Yes (94%)	Yes (85%)	No
Pulsed lavage	244 (43%)	52 (68%)	Femur: 494 (87%)	Femur: 199 (78%) Acetabulum: 170 (67%)	12 (57%)
Bone drying	499 (88%)	71 (92%)	NS	NS	NS
Application	Variable: gun (9%), other techniques	Variable: Manual (31%), Spatula (21%), gun (7%), finger packing (31%)	Femur: gun (95%), finger packing (4%)	Femur: gun (86%) Acetabulum: gun (32%)	Variable: manual (90%), gun (71%) for THA revision and TKA diaphysis
Cement applied to bone and implant	Femoral component: 62% Tibial component: 33% no consensus	NS	NS	NS	86%
Cemented implant	95% for the patella and tibia 80% for the femur	Tibia	Femur	Acetabulum and femur	NS
Pressurisation	NA	Tibia: gun (5%), other	Variable: manual (33%), pressurisation device (30%), both (36%)	Acetabulum: manual (89%)	Manual or gun (THA)

TKA; total knee arthroplasty; THA; total hip arthroplasty; TSA; total shoulder arthroplasty; TEA; total elbow arthroplasty; TAA; total ankle arthroplasty; NS; not specified; NA; not applicable; P; primary; R; revision.

5. Conclusion

This study demonstrated considerable heterogeneity in cementing techniques in a French university hospital, in keeping with reports from other countries. This heterogeneity can be ascribed to the absence of clear recommendations issued by scientific societies and to the variable and at times conflicting data published in the literature. Exchanges should be fostered with the goal of developing uniform cementing strategies. Consequently, a nationwide multi-centre survey of cementing practices in France would be welcome.

Disclosure of interest

Marine Barral: financial support with no direct benefit from Newbone.

Anthony Viste: financial support with no direct benefit from Adler.

JL Besse: consultant for Wright-Tornier.

MH Fessy: consultant for Serf, and Depuy.

Emmanuelle Carre: financial support with no direct benefit from Adler and Biomet.

L Lalande declares that she has no competing interest.

Funding

None.

Contribution

EC and AV conceived the study.

MB and EC developed the questionnaire and collected the study data.

AV validated the questionnaire.

MB, LL, EC, AV, and JLB analysed the study data.

MB, EC, LL, AV, JLB, and MHF drafted the manuscript.

All authors read and approved the final version of the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2018.11.022.

References

[1] Schlegel UJ, Bishop NE, Püschel K, Morlock MM, Nagel K. Comparison of different cement application techniques for tibial component fixation in TKA. Int Orthop 2015;39:47–54.
[2] Vaninbroukx M, Labey L, Innocenti B, Bellemans J. Cementing the femoral component in total knee arthroplasty: which technique is the best? Knee 2009;16:265–8.
[3] Delaunay C, Hamadouche M, Girard J, Duhamel A. SoFCOT Group. What are the causes for failures of primary hip arthroplasties in France? Clin Orthop Relat Res 2013;471:3863–9.
[4] Argenson JN, Boisgard S, Parratte S, Descamps S, Bercovy M, Bonnevialle P, et al. Survival analysis of total knee arthroplasty at a minimum 10 years' follow-up:

a multicenter French nationwide study including 846 cases. Orthop Traumatol Surg Res 2013;99:385–90.
[5] Lohmann CH, Hameister R, Singh G. Allergies in orthopaedic and trauma surgery. Orthop Traumatol Surg Res 2017;103(1, Supplement):S75–81.
[6] Russotti GM, Coventry MB, Stauffer RN. Cemented total hip arthroplasty with contemporary techniques. A five-year minimum follow-up study. Clin Orthop Relat Res 1988;235:141–7.
[7] Phillips AM, Goddard NJ, Tomlinson JE. Current techniques in total knee replacement: results of a national survey. Ann R Coll Surg Engl 1996;78:515–20.
[8] Nedungayil SK, Mehendele S, Gheduzzi S, Learmonth ID. Femoral cementing techniques: current trends in the UK. Ann R Coll Surg Engl 2006;88:127–30.
[9] Fischer CA, Kaszap B, Drexler C, Lehner B, Clarius M. Cemented total hip arthroplasty in Germany - update 2010. Z Orthopadie Unfallchirurgie 2012;150:309–17.
[10] Haute Autorité de Santé. Evaluation des ciments avec ou sans antibiotiques pour la fixation des implants articulaires [Internet]. Saint-Denis La Plaine: HAS; 2016. https://www.has-sante.fr/portail/upload/docs/application/pdf/2017-02/rapport_ciment_vf.pdf.
[11] Gergely RCR, Toohey KS, Jones ME, Small SR, Berend ME. Towards the optimization of the preparation procedures of PMMA bone cement. J Orthop Res 2016;34:915–23.
[12] Malchau H, Herberts P, Ahnfelt L. Prognosis of total hip replacement in Sweden. Follow-up of 92,675 operations performed 1978–1990. Acta Orthop Scand 1993;64:497–506.
[13] Ungers LJ, Vendrely TG, Barnes CL. Control of methyl methacrylate during the preparation of orthopedic bone cements. J Occup Environ Hyg 2007;4:272–80.
[14] Schlegel UJ, Siewe J, Delank KS, Eysel P, Püschel K, Morlock MM, de Uhlenbrock AG. Pulsed lavage improves fixation strength of cemented tibial components. Int Orthop 2011;35:1165–9.
[15] Breusch SJ, Norman TL, Schneider U, Reitzel T, Blaha JD, Lukoschek M. Lavage technique in total hip arthroplasty: jet lavage produces better cement penetration than syringe lavage in the proximal femur. J Arthroplasty 2000;15:921–7.
[16] Niki Y, Matsumoto H, Otani T, Tomatsu T, Toyama Y. How much sterile saline should be used for efficient lavage during total knee arthroplasty? Effects of pulse lavage irrigation on removal of bone and cement debris. J Arthroplasty 2007;22:95–9.
[17] Walker PS, Soudry M, Ewald FC, McVickar H. Control of cement penetration in total knee arthroplasty. Clin Orthop Relat Res 1984;185:155–64.
[18] Vanlommel J, Luyckx JP, Labey L, Innocenti B, De Corte R, Bellemans J. Cementing the tibial component in total knee arthroplasty: which technique is the best? J Arthroplasty 2011;26:492–6.
[19] Lutz MJ, Pincus PF, Whitehouse SL, Halliday BR. The effect of cement gun and cement syringe use on the tibial cement mantle in total knee arthroplasty. J Arthroplasty 2009;24:461–7.
[20] Mann KA, Miller MA, Pray CL, Verdonschot N, Janssen D. A new approach to quantify trabecular resorption adjacent to cemented knee arthroplasty. J Biomech 2012;45:711–5.
[21] Flivik G, Wulff K, Sanfridsson J, Ryd L. Improved acetabular pressurization gives better cement penetration: in vivo measurements during total hip arthroplasty. J Arthroplasty 2004;19:911–8.
[22] Oh I, Merckx DB, Harris WH. Acetabular cement compactor. An experimental study of pressurization of cement in the acetabulum in total hip arthroplasty. Clin Orthop Relat Res 1983;177:289–93.
[23] Lutz MJ, Halliday BR. Survey of current cementing techniques in total knee replacement. ANZ J Surg 2002;72:437–9.