Modern cementing techniques: The foundation for successful knee replacement surgery

Cemented fixation as part of total knee arthroplasty is considered the standard procedure in knee joint replacement. A prerequisite in successful treatment is the use of modern cementing techniques, which, amongst other things, improve cement penetration into the bone thus increasing primary stability of the implant. By combining the various elements of modern cementing techniques, optimum cementing results and a long implant life can be achieved.

Data from the Scandinavian register in particular shows that in comparison with total knee arthroplasty (TKR) based on cementless fixation, using cemented implants reduces the risk of revision surgery and extends the implant life. Due to the superiority of cemented TKR, TKR in Scandinavia and in Great Britain, has almost exclusively followed the cemented approach since the mid-1980s. Data from the Swedish knee implant register demonstrate a significantly higher risk of revision surgery (greater by a factor of 1.4) in the case of the uncemented approach compared with cemented TKR (Fig. 1, 95% confidence interval: 1.1–1.9; $p = 0.01$) (1). The Finnish register also shows that the combination of cemented TKR with local and systemic antibiotic prophylaxis reduces the risk of revision surgery (2).

It is widely accepted that a reduced risk of revision surgery has a positive impact on the life expectancy of the implant in TKR. This is indicated not least by the results of a number of pre-clinical and clinical studies. A meta-analysis of 15 randomised studies and observational studies indicated a longer implant life with TKR in the case of cemented fixation compared with cementless implant fixation (95% confidence interval: 2.7–6.5, $p < 0.0001$) (3).

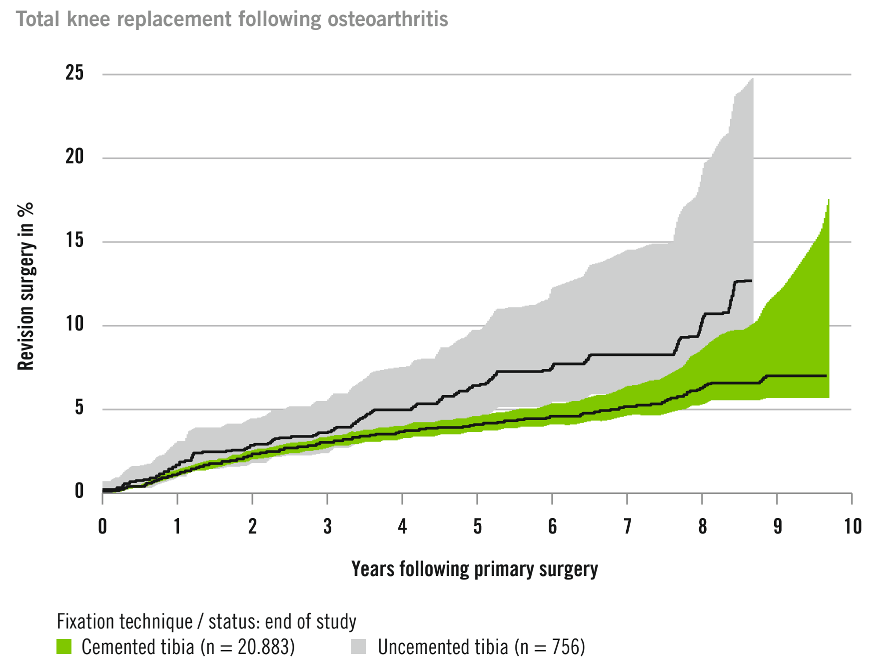

Fig. 1: Low risk of revision surgery in cemented TKR (1)

Elements of modern cementing techniques in knee surgery

- Tourniquet
- Drilling sclerotic bone surfaces
- Pulse lavage
- Drying the bone surface prior to cementation
- Using a vacuum mixing system
- Two-stage cementation of both TKR components
- Pressing the bone cement into the spongiosa
- Removal of all excess residual cement

Benefits of modern cementing techniques

The cementing technique used is a crucial factor in the long-term surgical outcome. The benefits for patients of cemented knee-implant fixation include in particular the immediate stability of the implant, which supports full weight-bearing right from the beginning. Bone cement compensates for irregularities in

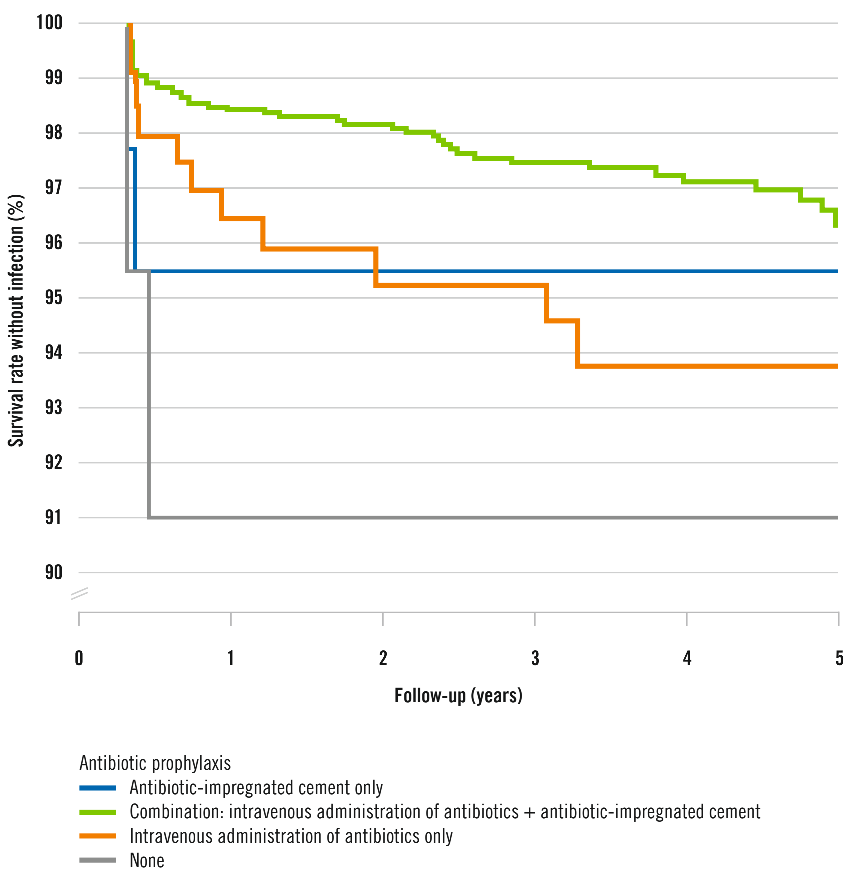

Fig. 2: Reduced risk of revision surgery in TKR through the combination of local and systemic antibiotic prophylaxis (2)

surrounding structures, fuses the implant securely to the bone and distributes the pressure load (4). The use of antibiotic-impregnated bone cement also reduces the risk of aseptic or septic loosening following TKR by lowering the risk of infection, see Fig. 2 (2, 5–7).

As the development of hip arthroplasty impressively demonstrates, the results of joint replacement can be clearly improved using modern cementing techniques, in terms of both implant life and the risk of revision surgery. This must also be consistently implemented in knee arthroplasty. The crucial objective is improved integration of the bone and bone cement through sufficient penetration of the cement into the spongiosa.

The elements involved in modern cementing techniques are described below:

Preparation of bone surfaces

Applying a tourniquet

Many surgeons apply a tourniquet intraoperatively in order to achieve a bloodless operating field (8). This simplifies implant placement and facilitates improved contact between the bone and the cement (9). Even if the tourniquet is not used for the entire duration of surgery, for example in patients where the risk of thromboembolism formation is high, or where postoperative pareses or pain are to be avoided (10, 11), a tourniquet should be applied for the actual cementation process. This measure has two objectives: Firstly, blood no longer escapes from the spongiosa, so that deep penetration of the bone cement into the bone is not impaired. Secondly, there is no risk of cement and blood mixing and thus compromising the mechanical properties of the bone cement.

Drilling sclerotic surfaces

The sclerotic bone surfaces that are typical particularly in arthritis of the knee may hinder integration of the cement and the bone. These surfaces must therefore be freshened using the drill. In doing so, several bore holes should be made that ensure improved integration (12). In this respect, the depth of the bore holes is less crucial than the ratio of the diameter of the drill to the depth of the bore hole. Using bovine femurs, Amirfeyz et al. were able to demonstrate that increased bone porosity and greater shear strength (13) correlate with one another. Accordingly, it was shown that drilling holes in the acetabulum prior to cementation increases resistance of the bone to torsion (14).

Cleaning and drying the bone bed

Pulse lavage

Cleaning the bone bed using a pulse lavage system has become a key aspect of modern cementing techniques (15). Pulse lavage safely removes blood, debris and fat, providing the basis for a stable interface between the cement and bone (16–19) due to deeper penetration of the cement into the spongiosa. This has also been demonstrated by data from an experimental study carried out using prepared tibiae, in which increased cement penetration was documented for TKR following pulse lavage compared with needle lavage (20). This results in significantly greater stability of the cemented components. Further investigations confirm the importance of pulse lavage based on radiological criteria. Accordingly, the lucency typical in prosthetic loosening was evident in 22% of patients whose tibial bone bed was treated with needle lavage, in comparison with just 4% of the patients who were treated using pulse lavage (21). In this study, the median penetration depth of the cement into the bone as determined radiologically was 2.6 mm compared with 1.5 mm without pulse lavage. As was demonstrated in the case of the hip, cleaning the bone bed using pulse lavage also reduces the risk of embolisms and respiratory or cardiovascular complications (22) associated with cement compression.

Drying the bone bed

If the bone bed is dry, the bone cement penetrates the spongiosa more deeply (23). Once pulse lavage has been used and the irrigation solution has been suctioned off, the bone bed should thus also be swabbed dry. Drying the bone bed is also considered an established element in modern cementing techniques, as indicated by a survey conducted among British orthopaedic specialists (24). In any case, the bone bed should not be cleaned, rinsed or swabbed dry until just before using the cement (25).

Selecting, preparing and mixing the bone cement

The quality of the bone cement as a material that transmits force between the implant and the bone plays an important role in cemented arthroplasty (26). Air bubbles can weaken the cement or encourage micro-fractures, which can then spread. The quality and prophylactic effectiveness in the case of infection of antibiotic-impregnated bone cement can be improved using modern cementing techniques (5, 27). This includes, for example, the selection of a bone cement with appropriate viscosity, the use of suitable antibiotics as well as the application of the vacuum mixing technique. The objective of these measures is to further increase the life expectancy of the artificial joint.

Antibiotics

The use of bone cement with local antibiotics reduces the rates of infection and revision surgery (28). Data from the Scandinavian implant register shows that local and systemic antibiotic prophylaxis play a crucial role in extending the life expectancy of implants (7). While antibiotics are generally added to the bone cement in primary arthroplasty, revision cements usually contain two antibiotics that synergistically complement each other (29). In this respect, industrially-produced bone cements offer considerable advantages in infection prophylaxis, with a highly standardised antibiotic mixture. This procedure facilitates consistently effective mechanical properties as well as reproducible antibiotic delivery (30). Industrially-produced bone cements are also distinguished by a high level of controlled quality with consistent material and processing properties (31–33).

Mixing cement under vacuum

Mixing cement under vacuum is a reliable method of producing homogenous bone cement with an optimum consistency and low porosity without any air bubbles (34, 35). In comparison with manual mixing in a bowl, the cement produced using vacuum mixing offers superior mechanical properties, e.g. with regard to fatigue strength. The risk of cement fracture is lower as a result (36–38). Another advantage in the case of vacuum mixing is that the cement is mixed under standardised conditions so that the quality of the cement produced is less dependent on the person mixing it.

Avoiding rinsing to cool the cement

When performing fixation in total arthroplasty, thermal energy is released during polymerisation of the bone cement. However, it has been demonstrated that despite performing surgery in a bloodless operating field, which limits the dissipation of heat via the bloodstream, there is no thermal damage of the bone or formation of heat necrosis as a result of the heat generated during polymerisation (39). Reasons discussed for the limited generation of heat include the thin cement coating as well as the effective conduction of heat via the implant (39, 40). Regarding the artificial knee joint, some authors nevertheless favour using cooled implants during surgery in a bloodless operating field, in order to reliably avoid tissue damage (41).

Using fluid to cool the operating field or cement is not recommended. There is a risk that antibiotics could leach out of the cement, thus impairing the prophylactic antibacterial impact of the cement.

Cementing the TKR components

Single-stage or two-stage cementation of the components can be performed (42). Single-stage cementation, in which all components are placed using the same cement mixture, is considerably more difficult than the two-stage approach, and is associated with a greater probability of the components not being ideally positioned (42). In two-stage cementation, the cement is mixed following an interval of 2–3 minutes.

During cementation, ensure that the bone surfaces are correctly coated so

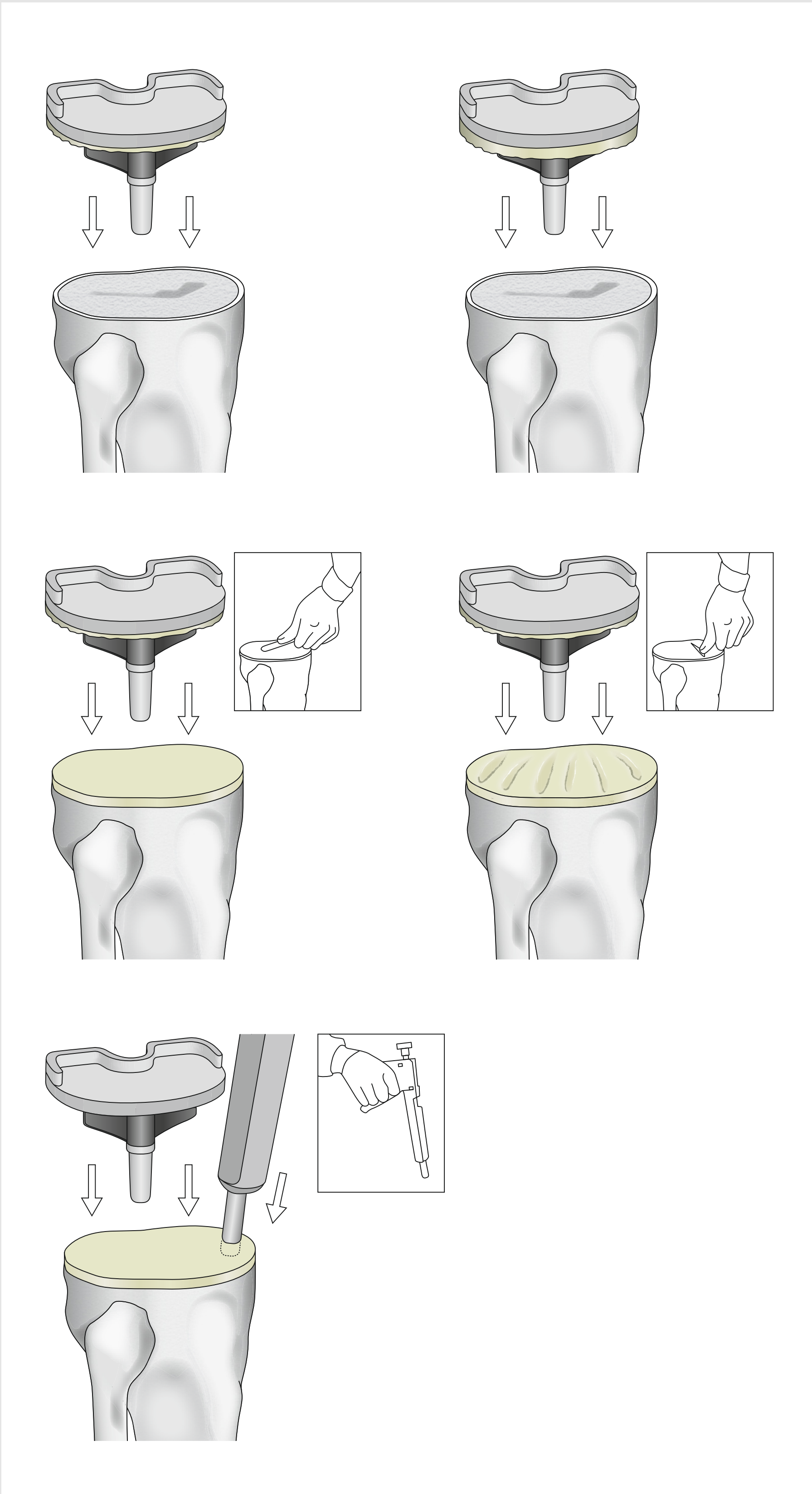

Fig. 3: Different cementing techniques in TKR (46)

that the cement can penetrate the bone bed to the required depth (4). The patellar and femoral components are cemented first. In doing so, the bone cement is generally placed on the anterior and distal bone surfaces, as well as on the posterior condyles of the femoral component (42, 43). The femoral component is impacted into position and all excess residual bone cement removed. The resulting cement coating is approx. 1 mm thick (42).

The second batch of cement is then used to place the tibial component used in TKR. In order to achieve primary stability, it is sufficient here to cement the bone cut, assuming that a cement penetration depth of at least 3 mm to approx. 5 mm is ensured (44–46). To achieve this, cement is applied to the implant and to the bone, and the cement is firmly pressed manually into the bone (Fig. 3). When cementing the proximal tibia using a cement gun it is necessary to ensure that the bone cement does not penetrate into the bone to a depth greater than 5 mm (46). Whether the implant stem should also be cemented is disputed. This would appear to depend on the design of the stem, amongst other things (4, 47). Generally speaking, cementing the stem most probably does not increase stability and makes any subsequent revision surgery more difficult (Fig. 4). Cementing the implant stem in the tibial medullary cavity is therefore not generally required. An experimental study using stereotactic analysis even concluded that additional cementing of the stem is detrimental with regard to the primary stability of the implant (48). As in cementation of the femoral component, any protruding cement particles must be removed so that they do not penetrate between the joint surfaces and cause friction (42).

One complication with regard to cementation is jamming of residual cement that might have been squeezed out in the posterior part of the femoral component as a result of strong flexion. This complication can be avoided by not applying cement to the posterior bone cuts. According to a study, the greatest penetration depth is achieved when bone cement is applied to the distal and anterior bone cuts as well as the anterior diagonal cut of the femoral component, and then pressed firmly into the spongiosa (43).

Conclusion

The elements of modern cementing techniques play a crucial role in the success of knee arthroplasty. The data currently available indicate that in the case of knee surgery too, modern cementing techniques are associated with lower loosening and revision rates as well as with a longer implant life. Moreover, cemented TKR allows primary stability to be achieved that allows for full weight-bearing. In addition to intraoperative measures, the use of bone cements with industrial addition of antibiotics is a crucial factor in successful treatment. These cements, particularly when vacuum mixing systems are used, ensure the consistently high standard of quality necessary in order to provide for effective knee arthroplasty that benefits the patient.

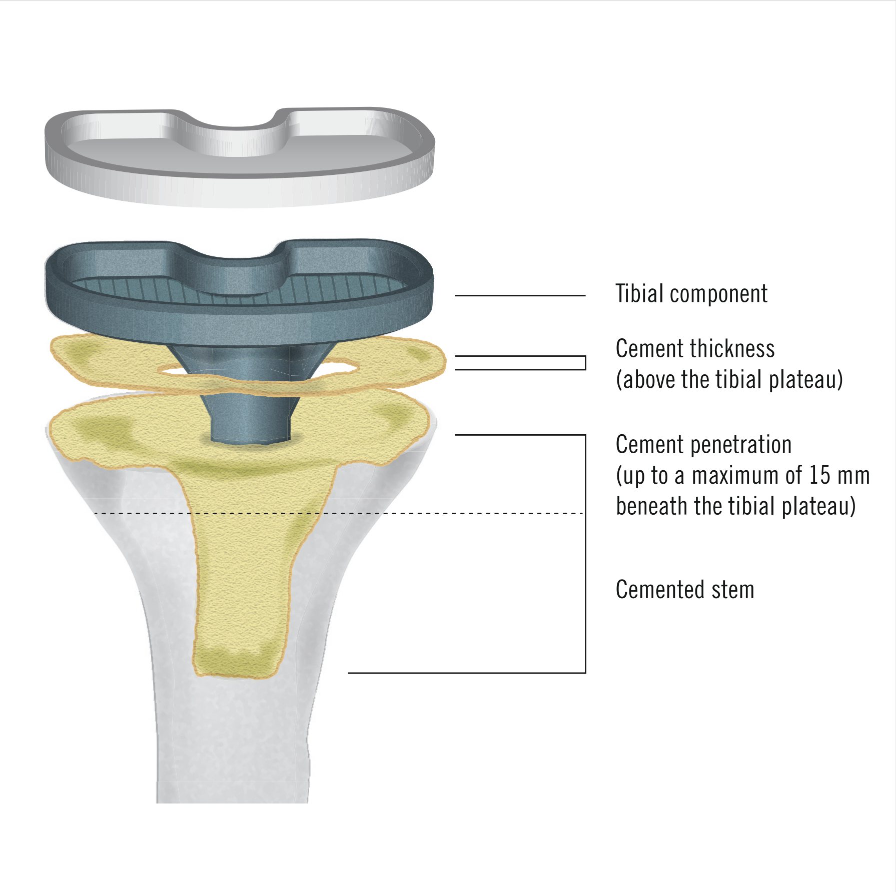

Fig. 4: Cross-section showing cemented TKR (49)

Literature

1. Robertsson O et al. The Swedish Knee Arthroplasty Register 1975–1997: an update with special emphasis on 41,223 knees operated on in 1988–1997. Acta Orthop Scand. 2001; 72 (5): 503–13.
2. Jamsen E et al. Risk factors for infection after knee arthroplasty. A register-based analysis of 43,149 cases. J Bone Joint Surg Am. 2009; 91 (1): 38–47.
3. Gandhi R et al. Survival and clinical function of cemented and uncemented prostheses in total knee replacement: a meta-analysis. J Bone Joint Surg Br. 2009; 91 (7): 889–95.
4. Cawley DT et al. Cementing techniques for the tibial component in primary total knee replacement. Bone Joint J. 2013; 95-B (3): 295–300.
5. Bourne RB. Prophylactic use of antibiotic bone cement: an emerging standard in the affirmative. J Arthroplasty. 2004; 19 (4 Suppl 1): 69–72.
6. Australian Orthopaedic Association. National Joint Registry. Annual Report. Adelaide. 2009.
7. Namba RS et al. Outcomes of routine use of antibiotic-loaded cement in primary total knee arthroplasty. J Arthroplasty. 2009; 24 (6 Suppl): 44–7.
8. Waddell J et al. Orthopaedic practice in total hip arthroplasty and total knee arthroplasty: results from the Global Orthopaedic Registry (GLORY). Am J Orthop (Belle Mead NJ). 2010; 39 (9 Suppl): 5–13.
9. Hernandez-Castanos DM, Ponce VV, Gil F. Release of ischaemia prior to wound closure in total knee arthroplasty: a better method? Int Orthop. 2008; 32 (5): 635–8.
10. Horlocker TT et al. Anesthetic, patient, and surgical risk factors for neurologic complications after prolonged total tourniquet time during total knee arthroplasty. Anesth Analg. 2006; 102 (3): 950–5.
11. Tai TW et al. Tourniquet use in total knee arthroplasty: a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2010; DOI: 10.1007/s00167-010-1342–7.
12. Miskovsky C, Whiteside LA, White SE. The cemented unicondylar knee arthroplasty. An in vitro comparison of three cement techniques. Clin Orthop Relat Res. 1992 (284): 215–20.
13. Amirfeyz R, Bannister G. The effect of bone porosity on the shear strength of the bone-cement interface. Int Orthop. 2009; 33 (3): 843–6.
14. Reading AD, Miles AW, Bannister GC. Keyholes in acetabular preparation. Hip Int 2002; 12: 163–5.
15. Röhrig H. Operation der Kniegelnksendoprothese In: Wirtz DC, ed. AE-Manual der Endoprothetik Knie. Berlin: Springer, 2011; p. 127–41.
16. Breusch SJ et al. Lavage technique in total hip arthroplasty: jet lavage produces better cement penetration than syringe lavage in the proximal femur. J Arthroplasty. 2000; 15 (7): 921–7.
17. Breusch SJ et al. [Significance of jet lavage for in vitro and in vivo cement penetration]. Z Orthop Ihre Grenzgeb. 2001; 139 (1): 52–63.
18. Breusch SJ, Malchau H. Bone preparation: femur. The well-cemented total hip arthroplasty. Berlin: Springer, 2005; p. 125–40.
19. Seeger JB et al. The effect of bone lavage on femoral cement penetration and interface temperature during Oxford unicompartmental knee arthroplasty with cement. J Bone Joint Surg Am. 2013; 95 (1): 48–53.
20. Schlegel UJ et al. Pulsed lavage improves fixation strength of cemented tibial components. Int Orthop. 2010; (im Druck).
21. Clarius M et al. Pulsed lavage reduces the incidence of radiolucent lines under the tibial tray of Oxford unicompartmental knee arthroplasty: pulsed lavage versus syringe lavage. Int Orthop. 2009; 33 (6): 1585–90.
22. Breusch SJ et al. Cemented hip prosthesis implantation decreasing the rate of fat embolism with pulsed pressure lavage. Orthopäde. 2000; 29 (6): 578–86.
23. Norton MR, Eyres KS. Irrigation and suction technique to ensure reliable cement penetration for total knee arthroplasty. J Arthroplasty. 2000; 15 (4): 468–74.
24. Phillips AM, Goddard NJ, Tomlinson JE. Current techniques in total knee replacement: results of a national survey. Ann R Coll Surg Engl. 1996; 78 (6): 515–20.
25. British Orthopaedic Association and British Association for Surgery of the Knee. Knee Replacement: A Guide to Good Practice. London: British Orthopaedic Association, 2011.
26. Kuehn KD, Ege W, Gopp U. Acrylic bone cements: mechanical and physical properties. Orthop Clin North Am. 2005; 36 (1): 29–39, v-vi.
27. Smeds S, Goertzen D, Ivarsson I. Influence of temperature and vacuum mixing on bone cement properties. Clin Orthop Relat Res. 1997 (334): 326–34.
28. Dunbar MJ. Antibiotic bone cements: their use in routine primary total joint arthroplasty is justified. Orthopedics. 2009; 32 (9).
29. Ensing GT et al. Copal bone cement is more effective in preventing biofilm formation than Palacos R-G. Clin Orthop Relat Res. 2008; 466 (6): 1492–8.
30. Neut D et al. The effect of mixing on gentamicin release from polymethylmethacrylate bone cements. Acta Orthop Scand. 2003; 74 (6): 670–6.
31. Lewis G. Properties of antibiotic-loaded acrylic bone cements for use in cemented arthroplasties: a state-of-the-art review. J Biomed Mater Res B Appl Biomater. 2009; 89B (2): 558–74.
32. Frommelt L, Kühn KD. Antibiotic-loaded cement. In: Breusch SJ, Malchau M, eds. The well-cemented total hip arthroplasty. Heidelberg: Springer, 2005; p. 86–92.
33. Jiranek W. Antibiotic-loaded cement in total hip replacement: current indications, efficacy, and complications. Orthopedics. 2005; 28 (8 Suppl): s873–7.
34. Dunne NJ, Orr JF. Influence of mixing techniques on the physical properties of acrylic bone cement. Biomaterials. 2001; 22 (13): 1819–26.
35. Wang JS et al. Porosity of bone cement reduced by mixing and collecting under vacuum. Acta Orthop Scand. 1993; 64 (2): 143–6.
36. Wixson RL, Lautenschlager EP, Novak MA. Vacuum mixing of acrylic bone cement. J Arthroplasty. 1987; 2 (2): 141–9.
37. Geiger MH et al. The clinical significance of vacuum mixing bone cement. Clin Orthop Relat Res. 2001 (382): 258–66.
38. Lidgren L, Bodelind B, Moller J. Bone cement improved by vacuum mixing and chilling. Acta Orthop Scand. 1987; 58 (1): 27–32.
39. Eitenmuller J, Wolbert R, Eisen E. [The effect of circulation on the polymerizing temperature of Palacos. An experimental study (author's transl)]. Arch Orthop Trauma Surg. 1981; 98 (1): 61–7.
40. Toksvig-Larsen S, Franzen H, Ryd L. Cement interface temperature in hip arthroplasty. Acta Orthop Scand. 1991; 62 (2): 102–5.
41. Biehl G, Harms J, Hanser U. [Experimental studies on heat development in bone during polymerization of bone cement. Intraoperative measurement of temperature in normal blood circulation and in bloodlessness]. Arch Orthop Unfallchir. 1974; 78 (1): 62–9.

42. Scuderi GR, Clarke H. Optimizing cementing technique. In: Bellemans J, Ries MD, Victor JMK, eds. Total knee arthroplasty. Berlin Heidelberg,: Springer, 2005; p. 223–7.

43. Vaninbroukx M et al. Cementing the femoral component in total knee arthroplasty: which technique is the best? Knee. 2009; 16 (4): 265–8.

44. Walker PS et al. Control of cement penetration in total knee arthroplasty. Clin Orthop Relat Res. 1984 (185): 155–64.

45. Kopec M et al. Effect of hand packing versus cement gun pressurization on cement mantle in total knee arthroplasty. Can J Surg. 2009; 52 (6): 490–4.

46. Vanlommel J et al. Cementing the tibial component in total knee arthroplasty: which technique is the best? J Arthroplasty. 2011; 26 (3): 492–6.

47. Bert JM, McShane M. Is it necessary to cement the tibial stem in cemented total knee arthroplasty? Clin Orthop Relat Res. 1998 (356): 73–8.

48. Skwara A et al. Primary stability of tibial components in TKA: in vitro comparison of two cementing techniques. Knee Surg Sports Traumatol Arthrosc. 2009; 17 (10): 1199–205.

49. Uhlenbrock, A et. al. Influence of time in-situ and implant type on fixation strength of cemented tibial trays – A post mortem retrieval analysis. Clinical Biomechanics. 2012; (27): 929–935