Cementing Techniques in Total Knee Arthroplasty

(Review Article)

Abstract

Total Knee Arthroplasty (TKA) is a surgery performed to treat patients with advanced knee osteoarthritis. Currently, about 95.3% of knee arthroplasties are performed using the cemented technique. Since the introduction of Polymethylmethacrylate (PMMA) cement, it has played a primary role in arthroplasty. Cementless fixation may lead to better survival rates in selected patients, while cemented TKA is believed to have lower infection rates. With the increasing number of TKAs, improving cementing techniques is essential to reduce primary TKA failure and avoid revision surgeries. A narrative review was conducted by searching the MEDLINE database from 2000 to 2024 to investigate the most appropriate cementing techniques in knee replacement. Recent studies have identified several factors affecting the results of cement placement in TKA, such as cement penetration depth, cementing technique, and cement viscosity. Preparing the bone surfaces before cementing is essential to ensure adequate cement penetration. Bone surfaces must be thoroughly dried before cementing. For optimal cement penetration, sclerotic surfaces should undergo drilling. Poor cementing technique is associated with loosening of the prosthesis leading to early or late joint replacement failure. Therefore, it is essential to use an accurate cementing method at the time of TKA to avoid aseptic loosening and, early failure of TKA.

Keywords: Total knee arthroplasty, Bone cements, Osteoarthritis.

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Introduction

Total Knee Arthroplasty (TKA) is an effective surgery for treating patients with advanced knee osteoarthritis. However, in some patients, this surgery faces early failure due to underlying factors(1). Currently, about 95.3% of knee arthroplasties are done using the Cemented technique(2,3). Since its introduction in 1950, Polymethylmethacrylate (PMMA) has played a major role as the cement material in arthroplasty(4). Some studies suggest that cementless fixation can provide better survival rates in younger or obese patients, while it is believed that cemented TKA has fewer infectious complications. However, there is no significant research showing a difference in survival rates between the two methods over a 10-year follow-up, regardless of age or BMI(5). With advancements in technology for producing polyethylene and implants, along with improvements in TKA surgical methods, aseptic loosening is now recognized as a leading cause of TKA failure and revision and in new studies, the prevalence of aseptic loosening has been reported in men and women under 50 years at 5.9% and 6.4%, respectively(2). Almost 11% of revisions performed in the first year after primary TKA are due to tibial component aseptic loosening at the cement-component interface. One study identified that the most important factors responsible for early prosthesis loosening at the cement-component interface of the tibial component were related to cement, including cement viscosity, cement placement method, and cement thickness(1). Aseptic loosening can lead to both early and late TKA failure and is more common in the tibial component than the femoral component, usually associated with improper cementing techniques(2,6).

With the increasing prevalence of TKA, it is essential to improve surgical techniques, particularly cementing techniques, to prevent increased failure rates in primary TKA and reduce the associated costs of revision surgery[2]. In general, the factors affecting cementation include cementing technique and the properties of the cement itself. To date, there is no consensus on which patients should receive cemented or cementless TKA[2]. In the following sections, we will explore the various factors that influence cement application to investigate the most appropriate cementing techniques for knee replacement.

Methods

This narrative review involved a search of the MEDLINE electronic database for articles published between 2000 and 2024. The inclusion was limited to articles on total knee replacement in adult patients. The exclusion criteria were non-English-language articles. All articles were initially screened based on title and abstract. Eventually, articles related to TKA cementing techniques were included. Also, the references of the extracted articles have been used as a source in writing this paper.

Results

The most important factors that influence the outcomes of cement application will be discussed below:

Cement Penetration

Studies have shown that the penetration of cement into the bone plays a key role in the strength of the prosthesis. Factors that improve cement penetration include: a dry and porous bone bed, venting of the tibial metaphysis, use of low or medium viscosity cement, hand packing, a working time of 3-4 minutes, low room temperature, and storing the cement at a low temperature[4].

Depending on the quality of the bone and the porosity of the cancellous bone, the cement can penetrate to varying degrees from the bone cut surface, creating a bond between the cement and the bone[7,8].

The amount of cement penetration into the cancellous bone indicates the stability of the implant in joint replacement with cementing[9]. For cement to penetrate at least one level of bone trabeculae, a cement thickness of 2 mm is required, and a thickness of 3-4 mm is optimal[10-12].

Cement penetration of 1.5 mm or less into the cancellous bone usually results in higher radiolucency and lower tensile strength associated with early implant micromotion[13]. Other factors affecting cement penetration include:

In cases where the tibial surface has sclerotic bone and cement penetration into the bone trabeculae may be impaired, drilling the sclerotic bone can improve cement penetration[14].

The use of pulsatile lavage increases the chance of cement penetration compared to conventional lavage as pulsatile lavage provides more effective debridement[13,15].

The bone can be adequately dried using suction and laparotomy sponges[16].

The negative pressure created by the holes in the tibial jig pins increases the chance of cement penetration into the bone[10,16,17].

The use of a spatula or finger packing can ensure adequate cement penetration[12,18].

Regarding the use of a cement gun, it is important to note that one study reported excessive cement penetration into the bone[12], while another study reported that the cement gun provided the greatest stability and the least micromovement[19].

In addition to the above, prolonging the setting time of the cement increases the flow of the cement and facilitates cement penetration. Using high-viscosity PMMA compared to medium-viscosity PMMA reduces the amount of penetration[20]. On the other hand, storing the cement at a low temperature and high humidity during mixing prolongs the setting time of the cement[4,21].

Mixing the cement under vacuum reduces the setting time by 2 minutes[22], and the time of application of the cement after mixing is inversely proportional to the amount of cement penetration[20].

Although the maximum setting temperature of cement during hip replacement is 48°C, it should be noted that the temperature of the knee joint with the use of a tourniquet and without the cooling effect of blood may be higher. Also, collagen denatures when exposed to temperatures above 56°C for an extended period[4,23].

A thick cement layer, high ambient temperature, and an increased monomer-to-polymer ratio increase the temperature of the cement during the setting phase[24].

Cementing Techniques

There are two primary techniques for applying cement in TKA[4]:

1. Fully Cementing: In this technique, the entire tibial plateau and tibial canal are filled with cement.
2. Surface Cementing: Here, only the surface of the tibial plateau is covered with cement.

There is ongoing debate about which technique is superior[4]. Previous studies have shown that full cementing provides better fixation, reduced micromovement, and greater long-term stability[25]. However, other studies have indicated that surface cementing offers adequate prosthesis stability and, by applying more load to the tibial plateau surface, helps maintain bone density and underlying bone structure[7,26]. Conversely, opponents of surface cementing argue that this technique does not provide sufficient fixation[4]. A laboratory study demonstrated that full cementing, compared to surface cementing, applies less stress to the cancellous bone beneath the tibial component and confirmed that full cementing leads to greater bone ingrowth in the proximal tibia[4].

Cement Viscosity

Cement can be classified into three categories based on viscosity[27,28]:

High Viscosity Cement (HVC): This cement has a short doughing phase and a long working phase.

- Medium Viscosity Cement (MVC): This cement has both a long doughing phase and a long working phase.
- Low Viscosity Cement (LVC): This cement has a long doughing phase and a short working phase.

An example of a high-viscosity cement is Palacos, which contains the antibiotic gentamicin and is manufactured by Zimmer[29]. An example of a medium-viscosity cement is Simplex, which contains the antibiotic tobramycin and is manufactured by Stryker[13].

In general, bone cements are sensitive to temperature, and any increase or decrease in temperature (whether from the environment, the cement components, or the mixing equipment) from the recommended 73 degrees Fahrenheit (23 degrees Celsius) affects the properties of the cement and its working time. It is recommended that the unopened product be stored at 73 degrees Fahrenheit for at least 24 hours before use. Manual handling of the cement and transferring body heat to it can shorten the working time of the cement.

Simplex Cement Mixing[13,30]: All of the powder should be placed in an empty container, and then the liquid should be added (the powder should not be added to the liquid). When the cement is to be manually applied at the implantation site, the mixing of the liquid and powder should continue until a doughy form is created that does not adhere to the surgical glove. This mixing process takes at least 4 minutes. For use with a cement gun, the mixing process takes 1 to 2.5 minutes. The cement is then loaded into the injection device and used.

Palacos Cement Mixing[29]: The liquid is first poured into a container, and then the powder is added and mixed with a spatula until it becomes doughy, which usually takes about 30 seconds. It is important to avoid trapping air in the cement during mixing. After mixing, the cement should rest for 1-2 minutes to reach the appropriate viscosity. The end of the resting phase is when the cement no longer adheres to the surgical glove, and at this point, a syringe or other cement application methods can be used. When the cement becomes rubbery, the working time of the cement is over, and the cement should not be applied.

Depuy Cement: Application and Technique Mixing: The powder is placed in a container first, followed by the liquid. Mixing continues until a doughy consistency is achieved that does not adhere to the surgical glove. The mixing process takes 2 minutes, and the working time is approximately 6 minutes. It is crucial to avoid trapping air during the mixing process. Cement Gun Use: When using a cement gun, the surgeon should visually assess the injection time. A small amount of cement should be extruded from the syringe to ensure that the cement surface is opaque and that there is no excessive flow of cement under gravity. It is recommended to place a cement restrictor in the prepared bone cavity at an appropriate depth before injecting the cement. Application: After filling the canal, sufficient pressure should be applied, and the component should be placed when the cement has sufficient viscosity to resist excessive component displacement. Note: Additives such as antibiotics should not be mixed with this cement as they can alter the cement's properties.

Expert Consensus on Cementing Technique (2023) Based on a 2023 Expert Consensus study, the following technique is presented as the most comprehensive cementing technique in TKA[2]:

- Bone Surface Preparation: Proper preparation of bone surfaces before cementation is essential to ensure adequate cement penetration into the bone and has been shown to significantly reduce component micromovement. Bone debris, blood, and fat should be removed using pulsatile lavage. Pulsatile lavage provides better cleaning, increases the depth of cement penetration into the bone, and improves the bond strength between the cement and bone(31,32).
- Drying: Bone surfaces should be completely dry before cementation. Drying can be achieved using suction, swabs, or intraosseous negative pressure suction catheters. Ensure that no debris, soft tissue, fat, or blood obstructs the spongy bone surface(17,33).
- Drilling: Sclerotic surfaces should be drilled to ensure adequate cement penetration. Drilling improves both cement penetration and pull-out strength(14,34).
- The Role of a Tourniquet in TKA and Cement Application Tourniquet Use: While tourniquets can provide a bloodless surgical field, improving visualization and creating a dry bone surface for cement application which can improve fixation(35), recent studies, such as that by Ahmed et al., suggest that their use in TKA might be associated with increased risks of postoperative complications like venous thromboembolism, infection, reoperation, and pain(36). Despite the initial advantages of a tourniquet-free technique, concerns remain about the long-term effects of cement contamination by blood, which could lead to poor component fixation and reduced implant survival. However, surgeons who continue to use tourniquets generally agree that it should at least be inflated during the cementing process(2).

Generally, these recommendations should be considered for cement application(2):

- Cement Viscosity and Additives: Medium or high-viscosity cement with an antibiotic is generally recommended.
- Mixing: Cement should be mixed under vacuum.
- Cement Application: Apply cement to both the posterior surfaces of the femoral and tibial components, as well as to the bone surfaces. Also, the tibial component keel should also be coated with cement.
- If there is blood, water or fat on the surface of the cement, it must be removed before placing the implant.
- Applying cement to the posterior aspect of the tibial component can prevent contamination and improve pull-out strength.
- Instruments may facilitate cement application during the wet phase, and cement guns have been shown to improve both cement penetration and coverage.
- Component Pressurization: Both femoral and tibial components should be pressurized using an impactor.
- Post-operative Positioning: The knee should be held in a fixed position during the cement curing phase to minimize micromovement.
- Avoid Extreme Positions: Avoid hyperflexion or hyperextension of the knee.

Conclusion

The cementing technique is associated with the loosening of the prosthesis and can lead to early or late joint replacement failure and the need for joint replacement.

Therefore, it is essential to use a precise cementing method at the time of placing the joint prosthesis to avoid aseptic loosening and, as a result, early failure of TKA.

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