CEMENT TECHNIQUE IN TOTAL KNEE ARTHROPLASTY

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Introduction

The longevity of cemented Total Knee Arthroplasty (TKA) is dependent on, among other factors, the cementing technique used. Unlike Total Hip Arthroplasty (THA), where there is a general consensus about proper cementing technique, there is significant variation in TKA cementing techniques. Good clinical results are multi-factorial; among these factors are proper handling and use of bone cement, type of bone cement, surgical technique and alignment of the components, precision of soft tissue balance, and implant design. This paper focuses on the importance of handling and use of bone cement during TKA.

Effect On Long-Term Implant Survivorship

It is important to note that cement considerations differ for TKA and THA. However, like in THA surgery, knee implants are known to fail at the cement-bone interface or at the cement-implant interface leading to implant loosening. Failure at the cement-bone interface may appear as radiolucent lines and is usually attributed to poor penetration of the cement into the bone. Failure at the cement-implant interface may be due to the poor interfacial strength of the cement to the implant.

In addition, variations in cementing technique may result in loosening and early revision, especially in those patients who place excessive loads on their replaced knees. In the case of THA, the femoral canal can be fully constrained and cement can be effectively pressurized into the cancellous bone by the use of a distal plug and a proximal pressurizer. In the case of TKA, the tibial plateau and the femoral condyles are not constrained, allowing the cement to escape from between the bone and implant instead of penetrating the cancellous bone adjacent to the implant.

Cement Behavior

From the start of mixing the powder and liquid together, the bone cement gradually increases in viscosity until it finally cures and hardens. During this process, it undergoes a number of phase changes. Soon after mixing, the cement is wet and sticky. Medium viscosity (MV) cements such as SMARTSET® MV Cement are relatively fluid soon after mixing and some surgeons prefer to apply the cement while it is still in this fluid state. Heating MV cements will increase the viscosity of the cement and reduce the time taken to reach a doughy state (start of the working phase). In this case, the surgeon must begin applying the cement earlier than he/she would if the cement had been mixed at room temperature to reduce the risk of working with cement that becomes too viscous to adequately penetrate into the bone. High viscosity (HV) cements such as SMARTSET HV Cement reach a doughy state almost immediately after mixing. Therefore heating HV cements will not only reduce setting time, but will significantly reduce the available working time of the cement.

The cement then reaches its dough state, where the surface of the cement becomes less sticky even though the main body of the cement remains sticky. This phase is usually known as the working phase of the cement. During this phase,
the cement can be manually handled by the surgeon, applied and digitally pressed into the bone or onto the implant. Alternatively, it can be extruded from a syringe, using a cement gun, and pressurized into the bone. At the end of this working phase, the cement enters an elastic phase and gradually warms via an exothermic reaction as the cement curing process accelerates. During this elastic phase, the cement surface is completely non-sticky and the cement no longer flows under pressure. In the case of using HV cement with TKA, the cement is applied to the bone and/or the implant and the implant is seated onto the bone early in the working phase. Applying cement directly to the implant at the beginning of the working phase improves the mechanical interlock with the implant. If the cement is used too late in its working phase, it will not maintain a good micro-interlock with the bone or mechanical interlock with the implant.

Bone cement undergoes physical and chemical changes when the powder and liquid are mixed together. The liquid begins to dissolve the surface of the polymer in the powder and then is gradually absorbed by the powder causing the powder to swell and the cement to increase in viscosity. The setting (or hardening) mechanism of bone cement is a chemical reaction, as a rough approximation, based on the Arrhenius equation, the rate of chemical reaction doubles for every 10°C/50°F increase in temperature. Therefore, both the dissolution of the polymer powder and the setting reaction of the cement are greatly affected by temperature. At higher temperatures, the cement will increase in viscosity and will set, or harden, faster.

**Note:** It is important to note that at a higher temperature, the working phase of the cement will also be significantly shorter. Temperature time charts are included in the cement Instructions for Use (IFU) to guide the surgeon when working with the cement at different temperatures.

It is critical at which temperature the surgeon is working with the cement, and is fully conversant with the cement’s characteristics and timings at that temperature and adjusts the surgical technique appropriately. In addition, storage and operating room conditions must be controlled such that the cement is consistent each time that the surgeon works with it.

It is important to store and prepare the powder and liquid at normal operating room temperatures. Some surgeons pre-warm the powder or liquid beyond the temperature range stated in the IFU to reduce the setting time of the cement. This fundamentally alters the handling characteristics of the cement and is not recommended. It not only reduces the setting time of the cement, but also can have a significant effect on reducing the working phase. This, in turn, will increase the risk of the cement being used too late in its working phase.

### Preparation of the Bone Surfaces

Clean gloves should be worn to keep implant and cement surfaces free from contaminants, such as aqueous fluids or lipids. A layer of aqueous fluids, fat or lipids between the cement and implant surfaces can increase the risk of mechanical interlock failure between the cement and the implant. Washing or cleaning all the bone surfaces (e.g. with pulsatile lavage) will remove loose cancellous bone, blood, fat and marrow, and allow uniform penetration of bone cement into the bone, therefore resulting in a stronger micro-interlock at the cement-bone interface. Removing fat and marrow from the bone will help to reduce the risk of embolic episodes, caused when fat and marrow are forced into the bloodstream. All bone surfaces should be clean and dry prior to applying the cement. Drying of the bone will improve cement contact with the bone. In addition, preventing blood contact with the cement will reduce the risk of blood laminations, which have the potential of reducing the mechanical strength of the cement. In areas of dense or sclerotic bone, drilling keying holes in the bone will assist in creating a greater degree of cement interdigation.

It is very important to achieve a good mechanical bond between the cement and the prosthesis. Use clean
gloves (augmented as desired with a spatula, cement gun, or syringe) to apply cement to the implant as early as possible in the working phase as this is the optimum time for cement application. Early application of the cement to a roughened (grit-blasted) implant surface has been demonstrated to increase the fixation strength of the cement to that metal surface. If applying doughy cement to both the implant and bone, implantation should be completed early in the working phase to ensure good "cement-cement" adhesion and reduce the risk of dry laminations, which can weaken the cement.

Many surgeons use a one-stage cementing technique, where one to two 40 g packs of cement are used to cement the tibial, femoral, and patellar all with the same mix of cement. The cement is allowed to set (harden) with the leg in full extension. This maneuver enhances pressurization of the cement into the bone. Limiting motion of the knee during curing of the cement is important to lessen the chance of implant separation from the cement or separation of the cement from the bone. An option used by some surgeons is a two-stage cementing technique. In this technique, a 20 – 40 g pack of cement is used to cement the tibial component and the cement is allowed to harden. Then a second 20 – 40 g pack of cement is used to cement the femoral and patellar components. Whether using a one-stage or two-stage cementing technique, good fixation to the bone and implant surface is achieved when the cement is handled and applied properly.

Cement Application & Implantation

Bone cement needs to flow into the features of the implant to maintain a mechanical interlock. To aid in mechanical interlock with the implant, features have been added to implants to improve the fixation to the cement. These features include a coarse surface finish, pegs or lugs, and cement pockets or undercuts.

Tibial Cementation

Generally the tibial component is cemented first. A 20 – 40 g pack of cement is normally used to provide a sufficient bed of cement to facilitate pressurization of the cement into the tibial bone. A thin layer of cement may not be sufficient to allow for optimal penetration of the cement into the bone especially around the periphery of the tibial plateau, and may result in relatively poor cement-bone adhesion. Cement is applied early in its working phase onto the undersurface of the tibial base and onto the cone of the implant. A thick layer of cement is then placed over the tibial plateau and down the hole for the tibial cone. Good pressurization of the cement will occur when the implant is inserted down into the hole for the tibial cone and onto the cement. To achieve an optimum cement-bone micro-interlock and enhance the mechanical bond between the bone and cement, an ideal depth of cement penetration into the bone of 3-4 mm is recommended.

Femoral Cementation

Once again, to achieve a good mechanical bond between the bone, the cement and the implant, a thick bed of cement should be placed onto the back of the implant or directly onto the exposed bone surface. Typically, cement is placed on the posterior condylar aspect of the femoral component and on the anterior aspect, anterior chamfers, and distal portion of the femoral bone. An impactor is used to impact the femoral component and to compress the cement into the bone. Using this technique, good levels of cement penetration into the bone can be achieved. Also, posterior extrusion of cement may be reduced by applying posterior cement to the implant rather than to the bone before the tibial insert is placed into the tibial base. When pressure is applied to the posterior aspect of the tibial component, it can cause the tibial component to lift anteriorly. Care should be taken to avoid the femoral component resting on the tibial component as the intended cement mantle could be affected.
Patella Cementation
Although not all surgeons choose to resurface the patella, those who do must take care to apply bone cement to the patellar implant while the bone cement is in its working phase, or dough phase. This can either be achieved through a one-stage cementing technique or two-stage cementing technique where the femoral and patellar components are cemented separately from the tibia. If applying cement to the bone, it should be pressed sufficiently into the bone surface and peg holes prior to introducing the patella implant. Alternatively, a thick bed of cement can be applied to the implant. A clamp is then used to fully pressurize the cement. The patella must be kept under compression using a patella clamp until the cement has fully hardened.

Note: During the end of the working phase and until the cement has fully cured, it is recommended that the implant is not disturbed, and in the case of TKA, is kept under pressure by keeping the knee in full extension. Hyper-extending and hyper-flexing of the knee before the cement has fully hardened should be avoided, as it may alter the flow of cement and disrupt the cement mantle or pull the cement away from the underside of the tibial component. If the cement separates from the implant during working phase, it is unlikely to reseat and form a strong mechanical interlock with the implant and could potentially lead to loosening at the cement-implant interface.

Final Pressurization and Cleaning
Excess cement or cement debris not removed from around the implants may scratch the implant and lead to polyethylene damage. In addition, excess cement which is not removed can dislodge and become a third body wear particle. In the case of the femoral component, retained posterior cement may prevent full flexion and generate debris, so care must be taken to ensure complete removal of extruded posterior cement, despite the difficult access. This is most easily accomplished by applying anterior traction to the distal femur before final insertion of the modular polyethylene insert with the knee flexed to 90 degrees. This opens the flexion gap and provides adequate access to extruded posterior femoral cement. There will be some extrusion of the cement from around the prosthesis, especially during implant seating, impaction, and leg extension. This cement requires complete removal before final hardening. An edged instrument should be used that will cut and remove the cement without dragging it from under the prosthesis. This will ensure that the edges around the implant are sealed to prevent the ingress of polyethylene debris. Dragging the cement could potentially leave a gap between the component and bone; therefore, compromising the cement mantle.

During this time period, if the cement is past its working phase, it may not re-attach to the tibial base, resulting in loosening at the cement-implant interface. It is only when the cement is fully cured that the knee should be taken through a range of motion. Care should be taken to ensure even loading to the tibial component. If the distribution of forces is unequal during final pressurization, the implants may move or cement may not penetrate into the cancellous bone equally in all zones, resulting in radiolucent lines.
The type of cement chosen for TKA cementation is based on surgeon preference as many differing types have been shown to work well if applied properly by the surgeon. I utilize DePuy CMW™ 1 Bone Cement because I like its handling characteristics and time to final hardening. With an operating room temperature of approximately 20°C/68°F, it has a working time of 8-9 minutes and a final cure time of about 10-12 minutes which is a sufficient time for me to precisely apply the cement and insert all three components without having wasted idle time waiting for the cement to cure. Additionally, this cement (originally CMW 1) has a multiple decade history of satisfactory performance.14 My scrub nurse mixes the cement utilizing a vacuum mixing device and places it into a cement gun. I prefer the cement to be mixed for one minute before the cement gun is handed to me. During cement mixing, the bone surfaces are irrigated with a pulsatile lavage system to remove debris and then thoroughly dried with a laparotomy sponge. Since cement cure times vary based on room temperature and humidity, I prefer to have the cement in my hands very early so I can assess the viscosity and determine when to apply it. Cement is applied to the undersurface of the components early in its working phase when it is in a lower viscosity state to enhance bonding to the undersurface of the implant.

Review of histology of the tibial bone-cement interface typically demonstrates excellent penetration of cement centrally around the tibial stem and in the central region of the tibial plateau. Cement in these regions is captured and therefore pressurizes well into the cancellous bone during component impaction. Peripherally, cement interdigitation into the bone is less predictable since it is not captured and can “escape” during component impaction. For this reason, I prefer to pressure-inject the cement into the peripheral regions of the proximal tibia to ensure good penetration. This method creates a good peripheral seal to limit ingress of future osteolytic chemicals generated from polyethylene wear debris. This pressure injection process is initiated as soon as the cement is viscous enough to touch without adhering to the surgical gloves. Also, before the tibial component is inserted, I utilize firm thumb pressurization of cement in the central canal hole to obtain good interdigitation and subsequent fixation. The cancellous bone of the central tibial metaphysis is typically less dense and therefore less supportive requiring added pressurization to ensure good central stem fixation.

Following cementation of the tibial component, the femoral component is applied in a similar fashion. The undersurface of the component is coated with cement to limit ingress of blood or marrow contents into the cement-implant interface. The bone is then coated with cement on its anterior and distal surfaces and the component is applied and impacted with special attention to avoid impacting the femoral component in a flexed orientation. The surgical assistant distracts the flexion gap to assist in removal of extruded cement and to avoid contact of the femoral and tibial components which could scratch the components and accelerate polyethylene wear. The trial modular bearing is then inserted and the knee is reduced. The knee is then placed in full extension to enhance uniform cement pressurization.

The patellar component is then cemented. Before cement application, the surgeon must inspect the resected cancellous surface of the patella. Typically, the lateral facet is sclerotic as the patellar resection often cuts at the level of the subchondral bone. If poor cancellous porosity is present, the sclerotic bone is perforated numerous times with a 1.5 mm drill bit to increase porosity and cement penetration into the patella. This maneuver is similarly done before cement application to any sclerotic bone present on the femoral or tibial surfaces. The patellar cement is applied in a doughy phase, pressurized via thumb compression into the lug holes and perforated bone, and then the patellar component is inserted and compressed with patellar compression device which is left in place until the cement is totally cured.

After all components have been inserted, the cement is evaluated. If adequate time remains before the cement begins to cure, the knee may be flexed and dislocated while being careful to insure that the tibial baseplate fixation is not disturbed. If it is determined that enough time is not available to perform a final removal of extruded cement, the knee is left in full extension until final curing has occurred and then later removed using a cement osteotome. One should avoid knee movement when the cement reaches the later stage of maturation to avoid separation of the cement from either the implant or bone. The method of cement removal is critical to avoid creation of third body micro-particulate cement debris which is commonly found embedded within retrieved polyethylene bearings. To achieve this, extruded cement should be cut with a sharpened instrument and removed in large fragments in contrast to “pulling” cement away from the implant with a curette which commonly creates miniature cement fragments which may be left in the joint following wound closure. Extensive pulsatile irrigation of the wound is always performed before wound closure to remove any residual bone or cement debris.
Conclusion

Knee implants are known to fail at the cement-bone interface or at the cement-implant interface leading to implant loosening. Much of the literature focuses on the cement-bone interface and commonly accepted practices are used, such as drilling key holes and bone washing to open the porous cancellous bone structure. Although a significant number of failures occur at the cement-implant surface, the root cause of the failure is not always fully understood. Unlike THA, there is significant variation in TKA cementing techniques and added to this, due to historical reasons or surgeon preference, high viscosity or medium viscosity cements are commonly used. This paper, through literature reviews and surgeon's personal experience, has attempted to capture fundamental principles, including practices around bone preparation and washing, cement pressurization, cement application, and minimizing movement before the cement has cured. Although there may be variation in cementing technique, understanding and applying these fundamental principles has the potential of reducing the risk of early implant loosening.

References:
