Cementing Best Practices in Total Knee Arthroplasty

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Survivorship and Reason for Revision has evolved over the last decade

Aseptic Loosening

Cumulative Incidence of Revision Diagnosis Total Knee Replacement

- Loosening/Lysis
- Infection
- Patellofemoral Pain
- Pain
- Instability

After year 2, most common reason for revision is loosening/lysis.


Full summary of all data is available from: https://aoanjrr.sahmri.com/annual-reports-2017

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Evolution of TKR Bone Cementing Techniques
Evolution of TKR Bone Cementing Techniques

Early first generation cementing techniques included\(^1\):

- limited bone-bed preparation
- hand mixing of cement in an open atmosphere
- stiff doughy cement introduced by hand
- digital pressurization

\(^1\) Breusch FJ, Malchau H Springer-Verlag Berlin Heidelberg, 2005
Evolution of TKR Bone Cementing Techniques

Key papers or milestones in TKR Cementing technique:

Bone-bed preparation

• Washing the bone using pulsed lavage, enhances cement penetration better than manual flushing alone\(^1\) and may improve the fixation strength of cemented tibial components\(^2\).

• Since bone cement has no adhesive properties, in areas of dense or sclerotic bone, drilling keying holes in the bone can assist in creating a greater degree of cement interdigitation\(^3\).

• As a dryer bone surface will result in deeper cement preparation, the cleaning and drying of bone directly before cement application is recommended\(^4\).

Evolution of TKR Bone Cementing Techniques

Cement Mixing

- Mixing bone cement in an open bowl can cause the inclusion of air into the cement if the cement is not adequately kneaded. Mixing in a vacuum system reduces the inclusion of air voids in the cured cement\(^1\). Voids in the cement can reduce the strength of the cured cement\(^2\).

Evolution of TKR Bone Cementing Techniques

Cement introduction and pressurisation

• To achieve adequate penetration of cement into bone, a study demonstrated that bone cement should be maintained at a pressure of at least 76 kPa (0.75 bar) for 5 seconds\(^1\). Furthermore, the use of a pressurized cement gun or cement syringe may increase the depth of the tibial cement mantle and reduce radiolucent lines when compared to cement applied by hand\(^2\).

• Pressurisation techniques include suction, digital application, syringe application, impaction and leg extension.

Evolution of TKR Bone Cementing Techniques

Cement Fixation

- Evidence suggests that a thicker cement mantle improves fixation strength and resistance to tensile and shear forces in the tibial component of total knee arthroplasty\(^1\). Studies have suggested that optimal fixation requires penetration of cement into the proximal tibia by 3 mm to 4 mm\(^2\).

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2. Cawley DT, Kelly N, Mcgarry JP, Shannon FJ, Instructional review 2013
Primary TKA 2018 –Cement Fixation

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Why Does Tibial Loosening persist?


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Hypothesis:

- Improved surgical efficiency is a necessary mandate of healthcare economics.
- Time efficiencies become an increasing focus in management of costs.
- Cementation techniques have evolved from sequential to simultaneous.
We theorized that the motion incurred during simultaneous component cementation may have an adverse effect on tibial fixation.
Asked 4 Research Questions

1. Does knee motion during the cementation process change tibial tray fixation strength?
2. Does knee motion influence marrow lipid contamination of the implant/cement interface?
3. Does marrow lipid contamination change implant fixation strength?
4. Does the type of tibial bone prep change tibial fixation strength when knee motion occurs during cementation?


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Simulated TKA Procedures were performed on thirty six lower extremity “pelvis to tip” cadaveric specimens (72 knees, age = 68 ± 11 years, height = 66 ± 3 inches, BMI = 24 ± 7, 13 female / 23 male).

Specimens with prior lower extremity injury, surgery, or compromised ligaments were excluded.

In matched specimens, on one side the implant component was held motionless with digital pressure until complete cement polymerization (“No Motion” cement technique)

In the opposite matched specimen, the tibial component was cemented at 2min and 30sec. At 7 minutes, the knee was taken through a standardized knee motion protocol simulating intra-operative simultaneous cementation and ligament examination (“Motion” cement technique)
Methods

• Prior to testing, each tibial implant and the associated prep instruments were laser scanned to establish the relative fit between the implant and prepared bone (3D Scanner HD and Scan Studio, NextEngine Inc, CA).

• Bone preparation instrumentation which leave a significant portion of the distal central fixation feature in contact with the surrounding cancellous bone were classified as ("No Clearance" prep).

• Bone preparation instrumentation which do not leave a significant portion of the distal central fixation feature in contact with the surrounding bone were classified as ("Clearance" prep).

Methods

• Each specimen was randomly assigned to receive one of 9 contemporary posterior stabilized primary TKA designs.


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Cohorts – No Motion/ Motion


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Testing

• Implanted tibiae were extracted from specimens, skeletonized.
• Trays were pulled proximally from the bone under displacement control at a rate of 5-mm/minute until failure of the cement interface, recording the peak retention force prior to failure.
• Trays were photographed to characterize the amount of surface contamination, the dark gray area is lipid stained (Fig. 5b).
• 3-dimensional triangular surface meshes of the tibial tray were overlaid and aligned to the images using Hypermesh (Altair), and elements corresponding to contaminated areas of the implant were identified.

Question 1: Does knee motion during the cementation process affect tibial tray fixation strength?

- Yes, knee motion during cementing caused a statistically significant reduction in fixation strength when comparing all implants in the “No Motion” and “Motion” cohorts ($p = 0.0013$).

- Average peak retention forces were reduced from $4647 \pm 1589$ N in the “No Motion” cohort to $3322 \pm 1753$ N in the “Motion” cohort.
Question 2: Does knee motion influence marrow lipid contamination of the implant/cement interface?

- **Yes**, knee motion during cement curing caused a statistically significant increase in lipid contamination of the tray fixation surfaces compared to the “No Motion” cohort ($p=0.0007$).

- Average contaminated surface areas were increased from $58\% \pm 19\%$ in the “No Motion” cohort to $81\% \pm 17\%$ in the “Motion” cohort.

All Trays/All Designs showed significant Lipid Contamination.


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Question 3: Does marrow lipid contamination affect implant fixation strength?

- Yes, a low negative correlation was observed between the amount of surface contamination and the resulting peak retention force across all specimens.

Question 4: Does the type of tibial bone prep affect tibial fixation strength when knee motion occurs during cementation?

- Yes, motion during cement curing with “Clearance” prep caused a significant reduction (p=0.0002) in retention force, but did not cause a statistically significant reduction in implants with “No Clearance” prep.
9 Different Designs - Individual implant designs are purposely blinded to highlight the correlations between motion during cementation, lipid contamination, and tibial bone preparation.
Conclusions

• **Knee motion during cementation adversely affects fixation and should be avoided**

• Knee motion introduces lipid contamination at the implant-cement interface which adversely affects tibial fixation strength

• If a surgeon prefers simultaneous cementation during TKA and is assessing ligamentous stability and ROM during cement curing, then designs with a “No Clearance” tibial prep are recommended.

• **Stress and movement of the knee during the cement curing phase is not recommended**, due to the inherent risk of motion with regard to lipid infiltration and degradation of tibial strength.


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KEY CEMENTING STEPS IN TOTAL KNEE ARTHROPLASTY

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DISCLOSURE

- Consultant: DePuy Synthes/ Corin
- Royalties:
  - DePuy Synthes/ Innomed / Wolters Kluwer
- Laboratory Research Support
  - DePuy Synthes
  - Porter Adventist Hospital
- Ownership Interest: Joint Vue
CEMENTING A TKA

**THA**
- Extensive Analyses Of Cement Technique
- General Consensus

**TKA**
- Less Scientific Analysis
- Wide Variations In Technique Are Utilized
- No Definite Consensus
CEMENT TECHNIQUE

Numerous Factors To Consider

• Bone Preparation
• Cement Type & Mixing Method
• Implant Preparation
  – Cement Precoating
• Cement Pressurization
  – Canal / Surface / Lipid Evacuation
• Implant Impaction
• Cement Removal
• Motion During Curing
BONE PREPARATION

- Assess For Sclerotic Bone
  - Resists Cement Penetration
- Penetrate With A Small Drill
  - Enhance Porosity
- Currette / Graft Any Bone Cysts
BONE PREPARATION

- Thoroughly Wash / Pulsatile Lavage
- Remove Debris & Enhance Cement Interdigitation
- Don’t Forget Posterior Femoral Condyles
BONE PREPARATION

- Krause, Miller, et al, CORR 1982
  - Pulsed Lavage + Pressure Injection → ↑ Fixation Strength

  - Pulsed Lavage Fixation → ↑ Fixation Strength & Cement Penetration Depth
  - Pressurizing With Cement Gun Couldn’t Overcome Not Using Pulsed Lavage
BONE PREPARATION

Schlegel, et al, Int Orthop 2010

• Technique Can Affect The Loosening Interface
• Enhanced Bone Penetration → Cement-Tray Debonding Predominates
  – Pulsatile Lavage / Pressure Injection
Reflected In Retrieval Analyses Demonstrating “Clean Tibial Baseplates” With Multiple Designs

Schlegel, et al, Int Orthop 2010
BONE PREPARATION

363 TKA Reviewed Radiographically

Compared Differing Cement Technique Methods

- Syringe Bone Rinse / Manual Packing
- Pulsed Lavage / Manual Packing

↑ Radiolucent Lines & ↓ Survivorship
If Pulsatilile Lavage Was Not Used

BONE PREPARATION

- Thoroughly Dry
  - ↓ Fluid @ Bone-Cement Interface
  - Enhance Cement Interdigitation
CEMENT TYPE

- Data Not Clear As To Superiority
- Some Reports Of ↑ Failure With High Viscosity Cement
- ? Inferior Bonding Of Cement To Implant

Complications - Other

Failure at the Tibial Cement–Implant Interface With the Use of High-Viscosity Cement in Total Knee Arthroplasty

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CEMENT PREP METHOD

- Hand Mixing Vs Vacuum Mixing?
- No Clear Survivorship Benefit Yet Reported In TKA
- Vacuum Mixing Advantages?
  - More Uniform Cement Mixing
  - Eliminates Cement Voids
COAT BOTH SURFACES?

- Compared 5 Cementing Techniques
- Fixation Assessed / Sawbones Model
- Component Coating Only: Not Recommended
- COAT BOTH IMPLANT & BONE

Vanlommel, Bellemans et al, J Arthroplasty, 2011
Precoat Implant With Cement Early
- Low Viscosity State / Better Implant Adherence
- Barrier To Lipid Infiltration Into The Cement-Metal Interface
CEMENT: PRESSURIZATION & PENETRATION INTO BONE

- Evidence Clearly Supports Use Of Pulsatile Lavage To Enhance Penetration

- **Questions:**
  - Are Use Of A Cement Gun Or Syringe Superior To Hand Pressurization?
  - Can Implant Design Enhance Cement Pressurization / Penetration?
  - Can Negative Pressure Enhance Interdigitation Of Bone Cement?
CEMENT PRESSURIZATION

- Compared Depth Of Cement Penetration
- Three Techniques
  - LVC Applied Via A Cement Gun
  - Standard Cement Via A Cement Syringe
  - Standard Cement Applied By Hand
- Mean Cement Penetration Depth
  - Cement Gun: 5.0mm / 4% RLL
  - Cement Syringe: 5.2mm / 4% RLL
  - Hand Penetration: 2.4mm / 28.6% RLL
- Gun / Syringe Pressurization Superior

Negative Pressure Technique Enhances Cement Penetration

2 Wolfe Needles Inserted

Suction Applied

SURFACE CEMENTATION ??

- Cadaveric Analysis
- Surface Vs. Surface + Stem Cementation
- Eccentric Load (Instron)
- Equivalent Fixation
  - 3.6 – 4.9 mm Of Uniform Cement Penetration

Clinical Data Varies

Most Favor Surface + Stem Cementation

If Surface Cementing, Need 3-4 mm Of Uniform Cement Penetration

- Retrievals Analyses:
  - 3-4 mm Of Uniform Penetration Infrequent

- Penetration > 5mm Risks Thermal Necrosis
CEMENT THE STEM?

- 12 Cadaveric Knees
- Fixation Assessed
  - No Stem Extension
  - Uncemented Short Central Stem
- Short Uncemented Stem Did Not Improve Fixation

CEMENT PENETRATION

- Histologic Analysis Typically Demonstrates ↑ Cement Penetration Centrally & ↓ Penetration Peripherally
  - Cement Escape
- Peripheral Pressurization?
- Escape Lessened With Cement Pockets
  - Vertullo, et al, J Arthroplasty 2004
CEMENT POCKET DESIGN

- Historical Cement Pockets: Vertical Walls
  - Lessen Cement Escape
  - Enhance Cement Penetration
  - Lessened Resistance To Tray Pull-Off
CEMENT POCKET DESIGN

Modern Cement Pockets: Undercut Walls
- Lessen Cement Escape
- Enhance Cement Penetration
- ↑↑↑ Resistance To Tray Pull-Off

CEMENTATION: MY TECHNIQUE

- Pulsatile Lavage
- Thoroughly Dry Bone
- Precoat Implant
  - Lessen Lipid Invasion Into Cement-Metal Interface
- Pressurize Central Canal
- Suction Lipid

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CEMENTATION: MY TECHNIQUE

- Pressurize Periphery
  - Cement Gun
  - Create A Peripheral Seal
- Implant Insertion
- Cut & Clear Cement
  - Limit Creation Of Cement Debris
- Limit Motion & Delay Final Bearing Impaction Until Cement Cured
TIBIAL PREPARATION:
MY TECHNIQUE
FEMORAL COMPONENT CEMENTATION: MY TECHNIQUE
NO MOTION DURING CURING

Delay Bearing Insertion Until Cement Cured!!
SUMMARY

Surgical Technique Keys:
- Drill Sclerotic Bone
- Cleanse / Dry The Bone
- Assure Good Cement Penetration
  - Especially At The Periphery
- Cut Then Clear Excess Cement
  - Avoid Microparticulate Cement
- Avoid Motion While Cement Cures
THANK YOU
Summary: what have we learnt?
Point One:

Bone preparation:

- Pulsatile lavage
- Dry bone
- Remove lipid
- Bone debris
Point Two:

Cement preparation:

• Mix at room temperature (73°F/23°C)
  • Do not heat monomer/powder
  • Fundamentally alters cement performance
  • Recommend high vacuum (7 atmos)
Point Three

Tibial cementing technique

• Cement on tibial prosthesis early
  • Cement on tibial plateau
  • Cement on tibial stem/cone
• Thick layer of cement over tibial bone
• Ensure high pressurization/penetration
Point Four

Femoral cement technique

• Early cement on femoral implant
• Focus on posterior condyles and anterior flange as both are placed into sheer
• Cement on femoral bone
Point Five

Cement recovery:

- Thick layer of cement technique
- There will be cement extrusion
- Sharp instrument to remove excess cement
- Avoid dragging cement from beneath implant
Point Six

Cement setting

- Do not rest the knee in flexion after femoral insertion
  - This can cause anterior tibial lift off
- Allow the cement to fully set in extension
- Do not force the knee into hyperextension during curing

- **Do not assess knee stability or ROM at this time**
  Possibly the most common error
Recommend reference document

Guidance for Cementing Total Knee Replacements

Cementing Total Knee Replacements

6.0 Summary and Conclusion
The following is a summary of recommended TKR cementing practices:

- Drill keyholes especially in areas of dense or sclerotic bone.
- Thoroughly wash all bone surfaces before cementing.
- Keep all surfaces clean and dry, including gloves, bone, and implant surfaces. Do not apply saline to the cement surface.
- Mix the cement under vacuum.
- Use the cement within its working time.
- Do not preheat the powder or liquid, especially with HV type cements, as this may impact the available working time. Follow the appropriate instructions for use on cement preparation.
- If a surgeon prefers simultaneous cementation during TKA and/or assessing ligamentous stability and ROM during cementing curing, thin designs with a ‘No Clearance’ tibial preparation are recommended. Steep and movement of the knee during cement curing phase is not recommended, due to the inherent risk of motion with regard to fluid infiltration and degradation of tibial tray fixation strength.
- Pressurize the cement by compression, use a thick layer of cement and impaction.
- Ensure that cement around the periphery of the implant has been well pressurized into the bone.
- Remove all extruded cement around the implant, making sure the implant is sealed by cement around its edges.
- Hold the cemented components under compression until the cement is fully set. Ensure that tibio-femoral compressive forces are perpendicular to the tibial axis. Curving in high flexion or hyper-extension may cause lifting of the tibial tray.
Question and Answer Session

With

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