ORS Orthopaedic Research Society

2018 ANNUAL MEETING

March 9, 2018 Pre-ORS • March 10–13, 2018 • Hyatt Regency New Orleans • New Orleans, LA

# WORKSHOP
# The Evolution of Total Joint Arthroplasty: A Historical Review of Hip, Knee, and Shoulder Prosthesis Design Advances

***(Organized by the ORS Industry Engagement Committee and ORS Orthopaedic Implants Section)***

Organizer:
Christopher P. Roche, MSE, MBA
Dennis Janssen, PhD

Speakers:
Evan Flatow, MD
John Callaghan, MD
Michael Mont, MD

**ORS 2018 Annual Meeting Workshop**: March 11, 2018 from 7-8:15am

**The evolution of total joint arthroplasty: a historical review of hip, knee, and shoulder prosthesis design advances**

*Organized by ORS Industry Engagement Committee (IEC) & ORS Orthopaedic Implants Section*
**Organizers**: Christopher P. Roche, MSE, MBA, Exactech, Inc., and Dennis Janssen, PhD, Radboud University Medical Center

**Speakers**:
*Historical Overview of Shoulder Arthroplasty Prosthesis Design*
Evan Flatow, MD, Mt. Sinai School of Medicine

*Historical Overview of Hip Arthroplasty Prosthesis Design*
John Callaghan, MD, University of Iowa

*Historical Overview of Knee Arthroplasty Prosthesis Design*
Michael Mont, MD, Cleveland Clinic

**Abstract**: Total joint arthroplasty is one of the most cost-effective and clinically successful medical procedures ever devised, with highly predictable outcomes for many different indications in the hip, knee, shoulder, and other diarthrodial joints. Prosthesis designs for each application have evolved over the past 50 years in an effort to improve long-term survivorship and patient satisfaction while also reducing the occurrence and severity of complications. Furthermore, expanding clinical usage and indications, and utilization of novel materials and manufacturing technologies have driven numerous prosthesis innovations that offer the potential to improve clinical outcomes. Thought leaders will describe the design lineages of hip, knee, and shoulder arthroplasty prosthesis designs, describing the ever-changing surgical, patient, engineering, and business factors that have influenced device requirements and led to the contemporary prosthesis designs. Finally, future advances in prosthesis design which offer the potential to improve clinical outcomes will be discussed.

**Speaker Outlines:**

**Historical Overview of Shoulder Arthroplasty Prosthesis Design**
**Evan Flatow, MD**
**Lasker professor of Orthopedic Surgery**
**President of Mount Sinai West Hospital**

- Early History
  - Themistocles Gluck designed first arthroplasties in late 1800s
  - First shoulder arthroplasty credited to Jules-Émile Péan in 1893
  - Many attempts at acrylic and polyethylene prostheses in 1950s
  - Little progress until Neer designed first prosthesis for proximal humerus fractures in 1951
  - First modern total shoulder introduced by Neer in 1974

- Anatomic shoulder replacements
  - Long-term outcomes :
    - Glenoid wear and loosening has compromised long-term outcomes of anatomic total shoulders
    - Manufacturers have tried to address these issues by modifying glenoid components
  - Metal-back glenoids have had higher revision and early failure rates than standard all-poly glenoids and should not be used on a routine basis
  - Cemented vs uncemented humeral fixation
    - Both alternatives have produced good results but there may a benefit to cementing certain implants in men
  - Managing Glenoid Bone Loss
    - Outcomes have been less favorable in patients with Walch glenoid B2 deformity
      - Companies have developed posteriorly augmented implants to address the B2 deformity
      - Having a posterior wedge implant allows to preserve the most bone while insuring stable support
    - In patients with severe bone loss or significant retroversion, inset glenoids may provide an option

- Reverse Shoulder arthroplasty
  - Term "Cuff Tear Arthropathy" coined by Neer in 1981
  - Noticed that patients with rotator cuff tears did more poorly and required a different type of implant to restore function
  - Designed the Mark I, Mark II and Mark III reverse total shoulders that produced poor results
  - In the 1970s, many different surgeons designed implants based on a fixed fulcrum system dependant on glenoid cementing and were fully-constrained
    - Led to premature failure of the glenoid component and high-revision rates

        - Some later designs shifted toward cementless glenoid fixation but still produced poor results with high complication rates
    - In 1985, Paul Grammont revolutionized the design of reverse shoulder arthroplasty
    - New design based on 4 key features :
        - Inherently stable prosthesis
        - Convex weight-bearing surface, concave supported part
        - Center of the sphere at or medial to glenoid rim
        - Center of rotation distalized and medialized to improve deltoid lever arm
    - First modern reverse was Delta III that had ½ sphere to further medialize center of rotation in order to improve deltoid mechanical advantage.
    - Modern reverses face new challenges
        - Inferior and posterior notching
        - Instability
        - Limited active ROM and strength
        - Glenoid component loosening and wear
        - Acromial Stress Fractures
    - New designs are focusing on these issues
    - Biomechanics of lateralizing glenoid component and reducing humeral neck-shaft angle
        - Lateralization of glenosphere produced higher loads and increased the deltoid force required to produce abduction
        - Lateralization of the humerus required less force from the deltoid to produce abduction
        - Lateralization of the humerus from 15mm to 35mm improves rotator cuff torque
        - Lateralizing glenosphere and reducing the neck-shaft angle produced significantly more impingement-free motion in all planes
    - Clinical Studies
        - Both lateralized and standard implants provided similar clinical outcomes at 2 years follow-up although the lateralized short-stemmed implant had more favorable radiological outcomes in terms of notching, glenoid lucency and bone resorption.
        - In a 2016 systematic review, there was a clinically and statistically significant difference in external rotation favoring the lateralized group

- Stemless Shoulder Designs
    - Resurfacing implants were introduced as alternatives to standard hemiarthroplasty in hopes of preserving bone for future revisions
    - Preserves the head so very difficult to expose glenoid for total shoulder arthroplasty
        - According to the Danish registry, revision rates have been higher in resurfacing hemiarthroplasties than in stemmed hemiarthroplasties
    - Stemless implants
        - Theoretically retain the same advantages of resurfacing implants (i.e. preservation of humeral shaft, easier revision, possibility of implantation in patients with post-traumatic deformity)

        - Involve making are similar head cut as for a stemmed implant making glenoid preparation and implantation much easier
        - Not yet FDA approved
        - Encouraging initial results showing similar short-term outcomes than traditional stemmed implants

- Patient-Specific Instrumentation and custom implants

    - Patient specific instrumentation systems have been developed by many manufacturers in order to improve accuracy among surgeons
        - Initial results have shown that the patient-specific instrumentation systems require more work to better control reaming and rotation of components
        - Vault reconstruction systems and custom implants are now being developed for patient who have severe deformity

- Thinking outside the box
    - Pyrocarbon interposition arthroplasty is a novel implant that has been designed for very young patients with osteoarthritis or osteonecrosis
    - Pyrocarbon has favorable tribologic and elastic properties minimizing joint wear
        - Pyrocarbon interposition arthroplasty has similar patient reported outcome scores to hemiarthroplasty but inferior to total shoulder arthroplasty
        - However, high-revision rates, high rates of bony erosion and lack of long-term data leaves significant questions about using this implant as an alternative to hemiarthroplasty

References:


1. Obermeyer, T., et al., *Midterm Follow-Up of Metal-Backed Glenoid Components in Anatomical Total Shoulder Arthroplasties.* Am J Orthop (Belle Mead NJ), 2015. **44**(9): p. E340-2.
2. Kelkar, R., et al., *Glenohumeral mechanics: a study of articular geometry, contact, and kinematics.* J Shoulder Elbow Surg, 2001. **10**(1): p. 73-84.
3. Wang, V.M., et al., *Biomechanical evaluation of a novel glenoid design in total shoulder arthroplasty.* J Shoulder Elbow Surg, 2005. **14**(1 Suppl S): p. 129s-140s.
4. Klepps, S., et al., *Incidence of early radiolucent glenoid lines in patients having total shoulder replacements.* Clin Orthop Relat Res, 2005(435): p. 118-25.
5. Robertson, D.D., et al., *Three-dimensional analysis of the proximal part of the humerus: relevance to arthroplasty.* J Bone Joint Surg Am, 2000. **82-a**(11): p. 1594-602.
6. Flatow, E.L., *Prosthetic design considerations in total shoulder arthroplasty.* Semin Arthroplasty, 1995. **6**(4): p. 233-44.
7. Soslowsky, L.J., et al., *Articular geometry of the glenohumeral joint.* Clin Orthop Relat Res, 1992(285): p. 181-90.
8. Soslowsky, L.J., et al., *Quantitation of in situ contact areas at the glenohumeral joint: a biomechanical study.* J Orthop Res, 1992. **10**(4): p. 524-34. Giles, J.W., et al., *Implant Design Variations in Reverse Total Shoulder Arthroplasty Influence the Required Deltoid Force and Resultant Joint Load.* Clin Orthop Relat Res, 2015. **473**(11): p. 3615-26.
9. Giles, J.W., et al., *The rotator cuff muscles are antagonists after reverse total shoulder arthroplasty.* J Shoulder Elbow Surg, 2016. **25**(10): p. 1592-600.

10. Chan, K., et al., *Does Humeral Component Lateralization in Reverse Shoulder Arthroplasty Affect Rotator Cuff Torque? Evaluation in a Cadaver Model.* Clin Orthop Relat Res, 2017. **475**(10): p. 2564-2571.
11. Flatow, E.L. and A.K. Harrison, *A history of reverse total shoulder arthroplasty.* Clin Orthop Relat Res, 2011. **469**(9): p. 2432-9.
12. Merolla, G., et al., *Grammont humeral design versus onlay curved-stem reverse shoulder arthroplasty: comparison of clinical and radiographic outcomes with minimum 2-year follow-up.* J Shoulder Elbow Surg, 2017.
13. Tashjian, R.Z., *CORR Insights((R)): implant design variations in reverse total shoulder arthroplasty influence the required deltoid force and resultant joint load.* Clin Orthop Relat Res, 2015. **473**(12): p. 3940-2.
14. Erickson, B.J., J.D. Harris, and A.A. Romeo, *The Effect of Humeral Inclination on Range of Motion in Reverse Total Shoulder Arthroplasty: A Systematic Review.* Am J Orthop (Belle Mead NJ), 2016. **45**(4): p. E174-9.
15. Knowles, N.K., L.M. Ferreira, and G.S. Athwal, *Augmented glenoid component designs for type B2 erosions: a computational comparison by volume of bone removal and quality of remaining bone.* J Shoulder Elbow Surg, 2015. **24**(8): p. 1218-26.
16. Boileau, P., et al., *Metal-backed glenoid implant with polyethylene insert is not a viable long-term therapeutic option.* J Shoulder Elbow Surg, 2015. **24**(10): p. 1534-43.
17. Davis, D.E., et al., *Total shoulder arthroplasty using an inlay mini-glenoid component for glenoid deficiency: a 2-year follow-up of 9 shoulders in 7 patients.* J Shoulder Elbow Surg, 2016. **25**(8): p. 1354-61.
18. Clitherow, H.D., C.M. Frampton, and T.M. Astley, *Effect of glenoid cementation on total shoulder arthroplasty for degenerative arthritis of the shoulder: a review of the New Zealand National Joint Registry.* J Shoulder Elbow Surg, 2014. **23**(6): p. 775-81.
19. Rasmussen, J.V., et al., *Outcome, revision rate and indication for revision following resurfacing hemiarthroplasty for osteoarthritis of the shoulder: 837 operations reported to the Danish Shoulder Arthroplasty Registry.* Bone Joint J, 2014. **96-b**(4): p. 519-25.
20. Berhouet, J., P. Garaud, and L. Favard, *Evaluation of the role of glenosphere design and humeral component retroversion in avoiding scapular notching during reverse shoulder arthroplasty.* J Shoulder Elbow Surg, 2014. **23**(2): p. 151-8.
21. Garret, J., et al., *Pyrocarbon interposition shoulder arthroplasty: preliminary results from a prospective multicenter study at 2 years of follow-up.* J Shoulder Elbow Surg, 2017. **26**(7): p. 1143-1151.
22. Churchill, R.S., *Stemless shoulder arthroplasty: current status.* J Shoulder Elbow Surg, 2014. **23**(9): p. 1409-14.
23. Wiater, J.M. and M.H. Fabing, *Shoulder arthroplasty: prosthetic options and indications.* J Am Acad Orthop Surg, 2009. **17**(7): p. 415-25.

**Historical Overview of Hip Arthroplasty Prosthesis Design**

**John J. Callaghan, MD**
**The Lawrence & Marilyn Dorr Chair**
**University of Iowa**

I. Early Development of Hip Replacement

A. Precursors to successful total hip replacement
1. Cup arthroplasty (Smith-Petersen)
2. Endoprosthesis i.e. Austin Moore

B. The initial breakthrough: Charnley low-friction arthroplasty
1. Why the Charnley total hip replacement was clinically successful
a. Use of cement to anchor the prosthesis to bone
b. Use of a metal-on-plastic articulation

C. One step backwards before moving forward
1. The rapid failure of Polytetrafluoethylene (PTFE – aka Teflon)

D. The second breakthrough
1. The story of finding a new bearing surface
2. Polyethylene for the acetabular component

II. Development of Cemented Femoral Components

A. Femoral component designs which protected cement (no sharp corners and were torsionally stable) Charnley design, T-28, HD-2

B. Collar, collarless controversy to preserve bone quality

C. Torsionally stable designs vs a taper wedge philosophy (Exeter)

D. Improvement in metallurgy to prevent stem fracture

E. Evolution of stem surface finish from satin to grit to polish

III. Development of Improved Cementing Technique

A. Hand packing cement

B. Cement gun to introduce cement

C. Cement pressurization
D. Porosity reduction

IV. Understanding the Biology of Component Failure

A. Cement disease

B. Particle disease (wear became the main culprit)

C. Mechanical vs biological mechanisms

V. The Move to Cementless Fixation from Cemented Fixation

A. Porous coated devices

VI. Development of Durable Bearing Surfaces

A. Recognition of polyethylene as the limitation to total hip arthroplasty durability (late 1990's)
1. Oxidation
2. Crosslinking

B. Development of options to traditional gamma in air polyethylene
1. Crosslinked polyethylene
2. Ceramic-on-ceramic
3. Metal on metal

C. The results of the change in bearing surface (late 1990's) at 15 years (2017)
1. Crosslinked polyethylene, minimal wear, minimal osteolysis, minimal failure
2. Metal-on-metal: relatively high failure from adverse local tissue response (ALTR)
3. Ceramic-on-ceramic, excellent durability, squeaking and liner chipping from impingement

D. Understanding the need for circumferential coating and the effective joint space: the gasket effect

E. Variations in femoral design
1. Fully coated vs proximally coated designs
2. Porous coating vs Hydroxyapatite vs textured titanium surfaces
3. Straight vs anatomic vs tapered
4. Use of modularity

VII. Cementless acetabular devices and fixation

A. Technique and designs providing stable fixation
1. Press-fit of the components
2. Screws and spikes for augmentation
3. Improvement in porous surface technology
a. Trabecular metal coatings
b. 3-D printing

VIII. Development of Optimal Femoral Head Size

A. Issue with stability vs wear

B. Smaller head size, less wear
1. Sliding distance (short)
2. Polyethylene thickness

C. Larger head sizes

1. Greater motion to impingement and dislocation (dropout distance)
2. Thinner polyethylene and longer sliding distance

IV. Future Challenges Providing 50 Year Durability in Active Patients and the Ultimately Stable Hip

A. Obstacles to 50 year durability
   1. Wear at bearing surfaces
   2. Wear of modular connection
      a. Femoral head tapers
      b. Modular acetabular liners

B. Improvement in Stability
   1. Robotic and computer assisted technology for optimal patient specific component positioning
   2. Newer designs including dual mobility bearings

R**eferences:**

1. Charnley J. Arthroplasty of the hip. A new operation. Lancet. 1961 May 27;1(7187):1129-32.
2. SMITH-PETERSEN MN, LARSON CB, et al. Complications of old fractures of the neck of the femur; results of treatment of vitallium-mold arthroplasty. J Bone Joint Surg Am. 1947 Jan;29(1):41-8.
3. Moore AT. The self-locking metal hip prosthesis. J Bone Joint Surg Am. 1957 Jul;39(4):811-27.
4. Charnley J. Using Teflon in arthroplasty of the hip-join. J Bone Joint Surg Am. 1966 Jun;48(4):819.
5. Waugh W. John Charnley: The Man and the Hip. Springer-Verlag. 1990.
6. Schulte KR, Callaghan JJ, Kelley SS, Johnston RC. The outcome of Charnley total hip arthroplasty with cement after a minimum twenty-year follow-up. The results of one surgeon. J Bone Joint Surg Am. 1993 Jul;75(7):961-75.
7. Amstutz HC, Yao J, Dorey FJ, Nugent JP. Survival analysis of T-28 hip arthroplasty with clinical implications. Orthop Clin North Am. 1988 Jul;19(3):491-503.
8. Skutek M, Bourne RB, Rorabeck CH, Burns A, Kearns S, Krishna G. The twenty to twenty-five-year outcomes of the Harris design-2 matte-finished cemented total hip replacement. A concise follow-up of a previous report. J Bone Joint Surg Am. 2007 Apr;89(4):814-8.
9. Fowler JL, Gie GA, Lee AJ, Ling RS. Experience with the Exeter total hip replacement since 1970. Orthop Clin North Am. 1988 Jul;19(3):477-89.
10. Mohler CG, Callaghan JJ, Collis DK, Johnston RC. Early loosening of the femoral component at the cement-prosthesis interface after total hip replacement. J Bone Joint Surg Am. 1995 Sep;77(9):1315-22.
11. Firestone DE, Callaghan JJ, Liu SS, Goetz DD, Sullivan PM, Vittetoe DA, Johnston RC. Total hip arthroplasty with a cemented, polished, collared femoral stem and a cementless acetabular component. A follow-up study at a minimum of ten years. J Bone Joint Surg Am. 2007 Jan;89(1):126-32.
12. Oh I, Bourne RB, Harris WH. The femoral cement compactor. An improvement in cementing technique in total hip replacement. J Bone Joint Surg Am. 1983 Dec;65(9):1335-8.
13. Callaghan JJ, Mallory TH. Optimal fixation for femoral components: cemented or cementless. J Arthroplasty. 1995 Jun;10(3):401-4.
14. Schmalzried TP, Callaghan JJ. Wear in total hip and knee replacements. J Bone Joint Surg Am. 1999 Jan;81(1):115-36.
15. Andersson GB, Gaechter A, Galante JO, Rostoker W. Segmental replacement of long bones in baboons using a fiber titanium implant. J Bone Joint Surg Am. 1978 Jan;60(1):31-40.
16. Crowninshield RD, Muratoglu OK; Implant Wear Symposium 2007 Engineering Work Group. How have new sterilization techniques and new forms of polyethylene influenced wear in total joint replacement? J Am Acad Orthop Surg. 2008;16 Suppl 1:S80-5.
17. Lachiewicz PF, Kleeman LT, Seyler T. Bearing Surfaces for Total Hip Arthroplasty. J Am Acad Orthop Surg. 2018 Jan 15;26(2):45-57.

18. Bedard NA, Callaghan JJ, Stefl MD, Willman TJ, Liu SS, Goetz DD. Fixation and wear with a contemporary acetabular component and cross-linked polyethylene at minimum 10-year follow-up. J Arthroplasty. 2014 Oct;29(10):1961-9.
19. Greiner JJ, Callaghan JJ, Bedard NA, Liu SS, Gao Y, Goetz DD. Fixation and Wear With Contemporary Acetabular Components and Cross-Linked Polyethylene at 10-Years in Patients Aged 50 and Under. J Arthroplasty. 2015 Sep;30(9):1577-85.
20. Davies AP, Willert HG, Campbell PA, Learmonth ID, Case CP. An unusual lymphocytic perivascular infiltration in tissues around contemporary metal-on-metal joint replacements. J Bone Joint Surg Am. 2005 Jan;87(1):18-27.
21. D'Antonio JA, Capello WN, Naughton M. High survivorship with a titanium-encased alumina ceramic bearing for total hip arthroplasty. Clin Orthop Relat Res. 2014 Feb;472(2):611-6.
22. Callaghan JJ, Fulghum CS, Glisson RR, Stranne SK. The effect of femoral stem geometry on interface motion in uncemented porous-coated total hip prostheses. Comparison of straight-stem and curved-stem designs. J Bone Joint Surg Am. 1992 Jul;74(6):839-48.
23. Hennessy DW, Callaghan JJ, Liu SS. Second-generation extensively porous-coated THA stems at minimum 10-year followup. Clin Orthop Relat Res. 2009 Sep;467(9):2290-6.
24. Takenaga RK, Callaghan JJ, Bedard NA, Liu SS, Klaassen AL, Pedersen DR. Cementless total hip arthroplasty in patients fifty years of age or younger: a minimum ten-year follow-up. J Bone Joint Surg Am. 2012 Dec 5;94(23):2153-9.
25. Slaven SE, Purcell RL, Mack AW, Bedard NA, Warth LC, Callaghan JJ. Results of Porous-Coated Anatomic Total Hip Arthroplasty without Cement at 25 to 30 Years: A Concise Follow-up of a Previous Report. J Bone Joint Surg Am. 2017 Oct 4;99(19):1647-1653.
26. Won YY, Dorr LD, Wan Z. Comparison of proximal porous-coated and grit-blasted surfaces of hydroxyapatite-coated stems. J Bone Joint Surg Am. 2004 Jan;86-A(1):124-8.
27. Louboutin L, Viste A, Desmarchelier R, Fessy MH. Long-term survivorship of the Corail™ standard stem. Orthop Traumatol Surg Res. 2017 Nov;103(7):987-992.
28. Carlson SW, Goetz DD, Liu SS, Greiner JJ, Callaghan JJ. Minimum 10-Year Follow-Up of Cementless Total Hip Arthroplasty Using a Contemporary Triple-Tapered Titanium Stem. J Arthroplasty. 2016 Oct;31(10):2231-6.
29. Stefl MD, Callaghan JJ, Liu SS, Pedersen DR, Goetz DD, Johnston RC. Primary cementless acetabular fixation at a minimum of twenty years of follow-up: a concise update of a previous report. J Bone Joint Surg Am. 2012 Feb 1;94(3):234-9.
30. Della Valle CJ, Mesko NW, Quigley L, Rosenberg AG, Jacobs JJ, Galante JO. Primary total hip arthroplasty with a porous-coated acetabular component. A concise follow-up, at a minimum of twenty years, of previous reports. J Bone Joint Surg Am. 2009 May;91(5):1130-5.
31. Poultsides LA, Sioros V, Anderson JA, Bruni D, Beksac B, Sculco TP. Ten- to 15-year clinical and radiographic results for a compression molded monoblock elliptical acetabular component. J Arthroplasty. 2012 Dec;27(10):1850-6.
32. Joglekar SB, Rose PS, Lewallen DG, Sim FH. Tantalum acetabular cups provide secure fixation in THA after pelvic irradiation at minimum 5-year followup. Clin Orthop Relat Res. 2012 Nov;470(11):3041-7.
33. Maxian TA, Brown TD, Pedersen DR, Callaghan JJ. The Frank Stinchfield Award. 3-Dimensional sliding/contact computational simulation of total hip wear. Clin Orthop Relat Res. 1996 Dec;(333):41-50.
34. Elkins JM, Callaghan JJ, Brown TD. The 2014 Frank Stinchfield Award: The 'landing zone' for wear and stability in total hip arthroplasty is smaller than we thought: a computational analysis. Clin Orthop Relat Res. 2015 Feb;473(2):441-52.
35. Golish SR, Kurtz SM, Boyan BD. Can 3D printing revolutionize orthopaedic devices? AAOS Now. Jan 2018.

**Historical Overview of Total Knee Arthroplasty Prosthesis Design**

**Michael A. Mont, MD**
**Department of Orthopaedic Surgery**
**Cleveland Clinic**

**Early prosthetic models:**

- Soft tissue interposition for construction
- Resection arthroplasty
- Hinged arthroplasty
- Campbell metallic interposition femoral mold
- Massachusetts General Hospital interposition prosthesis

**Resurfacing and condylar protheses:**

- Macintosh: acrylic then later metallic tibial plateau prosthesis
- Mckeever prosthesis: similar concept and wider utilization
- Gunston modifications: polycentric prothesis

**Evolution of modern total knee arthroplasty (TKA):**

- Freeman-Swanson prosthesis: pioneering the technique and design and introduction of the concept of ligament balancing and soft tissue releasing
- The Hospital for Special Surgery duocondylar knee (1971)
- Duopatella knee (Ranawat, 1974)
- Total condylar knee (Insall, 1974)
- The anatomic vs. functional protheses
- Modularity and Eftekhar Mark knees
- David Murray's variable axis

**Early cruciate retention design:**

- Yamamoto and Kodoma prosthesis: the first cementless condylar cruciate-sparing total knee
- Townley's design with cruciate retention, patellar resurfacing
- Geomedic/metric knee and posterior cruciate ligament (PCL) retention
- Porous coated anatomical knee (PCA) and cementless fixation

**Current prosthesis design:**

- Fixed-bearing, surface replacement prostheses:
  - Traditional cruciate-retaining and posterior-stabilized prosthesis
- Guided motion prostheses
- High-flexion and gender-optimized prostheses
- Cementless fixation
- Mobile-bearing prostheses
- Constrained prostheses
  - Constrained unlinked prostheses
  - Constrained rotating hinge prostheses

**Evolution of design features:**

- Articular geometry
- Design and fixation of the tibial component
- Modular augments and stems
- Patellar resurfacing and configuration

**Future perspectives:**

- Robotic and navigation technology
- Cementless fixation
- Conclusion

**References:**


1. Kane RL, Saleh KJ, Wilt TJ, Bershadsky B (2005) The functional outcomes of total knee arthroplasty. J Bone Joint Surg 87(8):1719–1724
2. Gunston FH (1971) Polycentric knee arthroplasty. Prosthetic simulation of normal knee movement. J Bone Joint Surg Br 53(2):272–277
3. Freeman MA, Swanson SA, Todd RC (1973) Total replacement of the knee using the Freeman-Swanson knee prosthesis. Clin Orthop Relat Res 94:153–170
4. Ranawat CS, Shine JJ (1973) Duo-condylar total knee arthroplasty. Clin Orthop Relat Res 94:185–195
5. Insall J, Scott WN, Ranawat CS (1979) Te total condylar knee prosthesis. A report of two hundred and twenty cases. J Bone Joint Surg 61(2):173–180
6. Insall JN, Lachiewicz PF, Burstein AH (1982) The posterior stabilized condylar prosthesis: a modification of the total condylar design. Two to four-year clinical experience. J Bone Joint Surg 64(9):1317-1323
7. Murray DG (1979) Total knee replacement-state of the art. Jefferson Orthop J IX:6
8. Hungerford DS, Krackow KA (1985) Total joint arthroplasty of the knee. Clin Orthop Relat Res 192:23–33
9. Ranawat AS, Rossi R, Loreti I, et al. (2004) Comparison of the PFC Sigma fxed-bearing and rotating-platform total knee arthroplasty in the same patient: short-term results. J Arthroplasty 19(1):35–39 52. Ranawat CS, Komistek RD, Rodriguez JA, et al. (2004)
10. In vivo kinematics for fxed and mobile-bearing posterior stabilized knee prostheses. Clin Orthop Relat Res 418:184–190