Medial-Pivot Design Concept

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Key need-to knows in Total Knee Arthroplasty

- Which kinematics are found in the natural knee?
- What is J-curve kinematics?
- What is Single Radius kinematics?
- What is Medial Pivoting Kinematics?

- How do they all compare?

Total Knee Arthroplasty Nowadays

- Although TKA is an excellent means of relieving pain, studies have shown that TKA is overwhelmingly **marginal in restoring function after surgery.**[1-2]
- After decades of improvement to technique and implant design in TKA, **20% of patients** continue to remain unsatisfied following TKA.[3]
- **Younger patients are choosing TKA**, and they are expecting high function following surgery.

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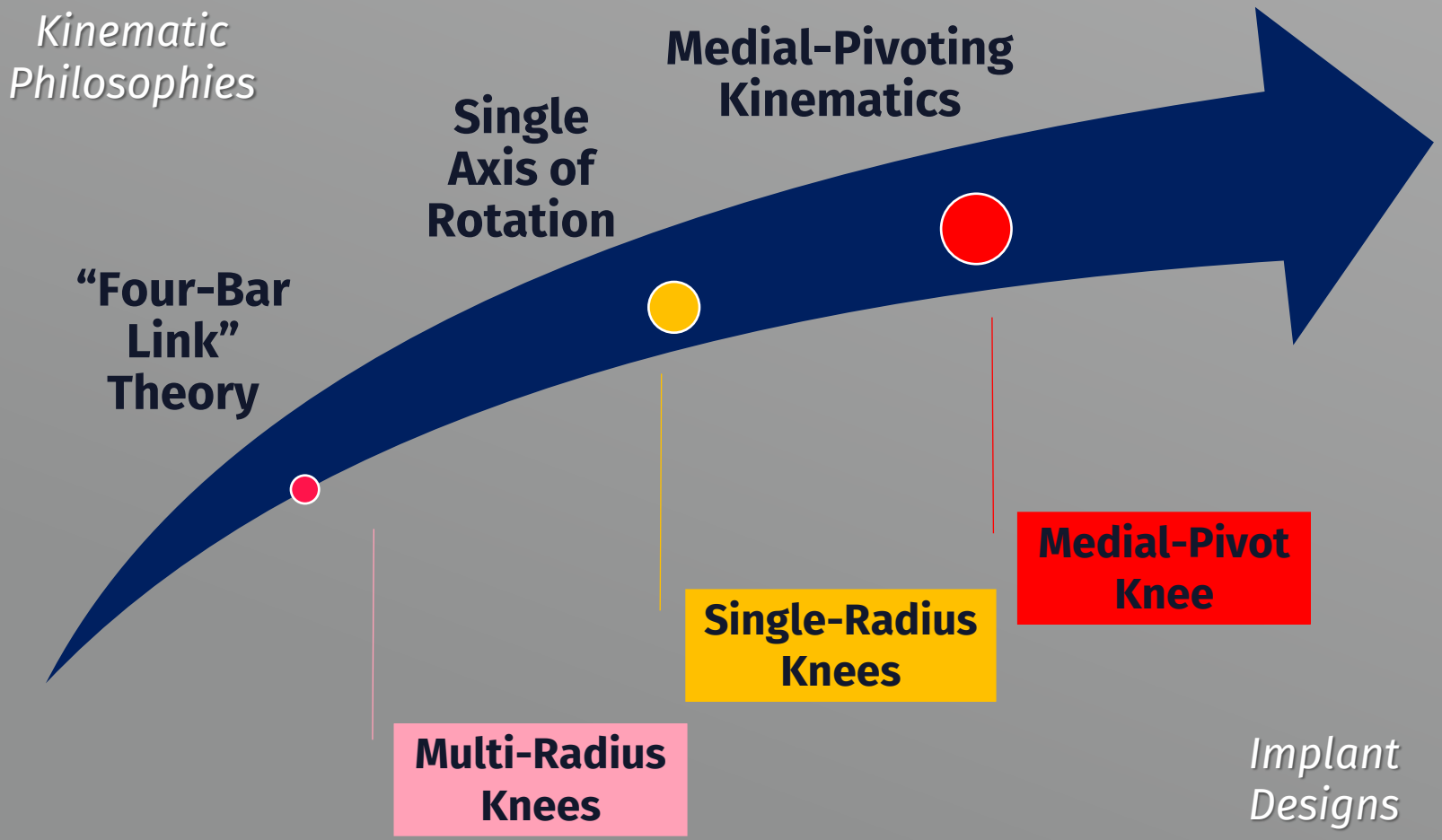
Linking Kinematic Philosophies to Implant Design



Linking Kinematic Philosophies to Implant Design

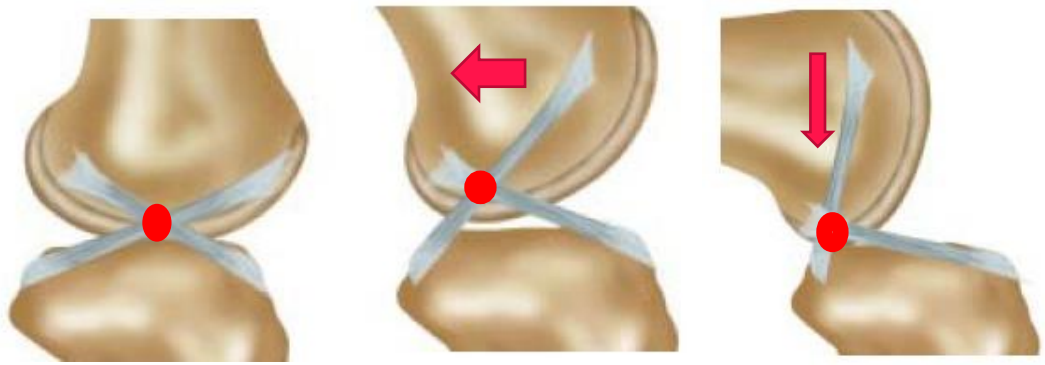
1st Generation:

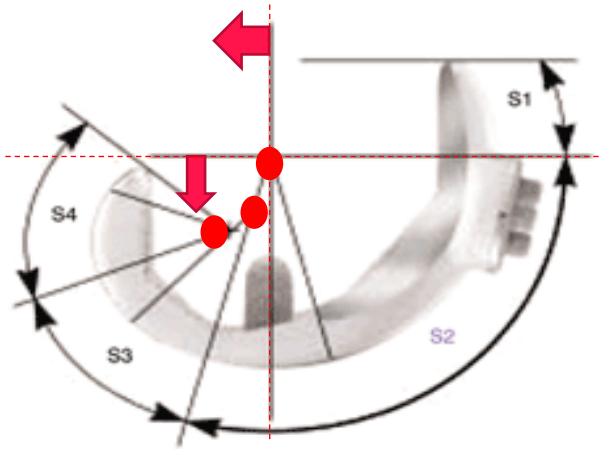
<u>"Four-Bar Link" Theory (70's–90's):</u>

- *"The kinematics of the knee are guided by a four-bar link."*[4]
- Kinematics of Four-Bar Link = Rollback

<u>Multi-Radius Knees:</u>

- Designed to produce rollback
- Rollback dictates limited tibiofemoral conformity
- Commonly associated with anterior sliding, instability, and anterior knee pain
- ***Examples*:**
  - Vanguard, Journey II, Persona



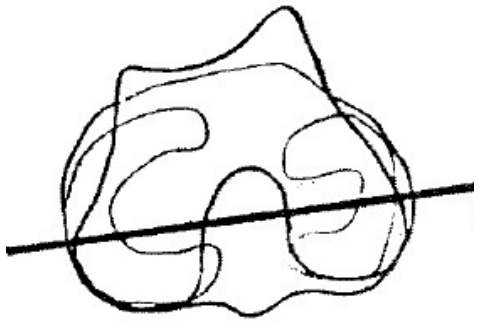


Linking Kinematic Philosophies to Implant Design

2nd Generation:

Single-Axis of Rotation (Early 90's):

- Hollister AM. The axes of rotation of the knee. 1993.[5]
  - Flexion – extension axis
  - Longitudinal rotation axis passes through center of tibia



Single-Radius Knees:

- Designed to produce symmetric rollback
- Lack of tibiofemoral congruency
- Commonly associated w/instability
- ***Examples*:**
  - Stryker Triathlon

Half of the story!

Multi-radius and single radius knees

J-Curve Femurs were designed with decreasing radii to stimulate roll back. Later a single radius femur was designed to maintain constant collateral tension.

Implants were designed to roll back over a non-congruent tibial insert.

1st Generation:

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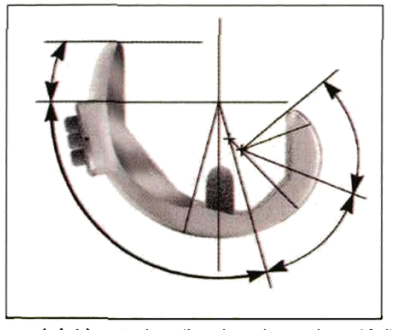

2nd Generation:

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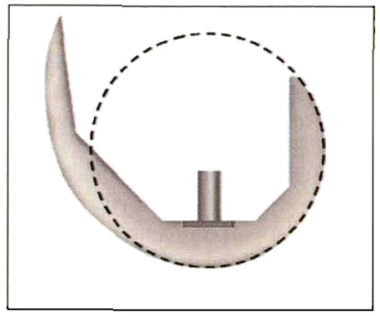
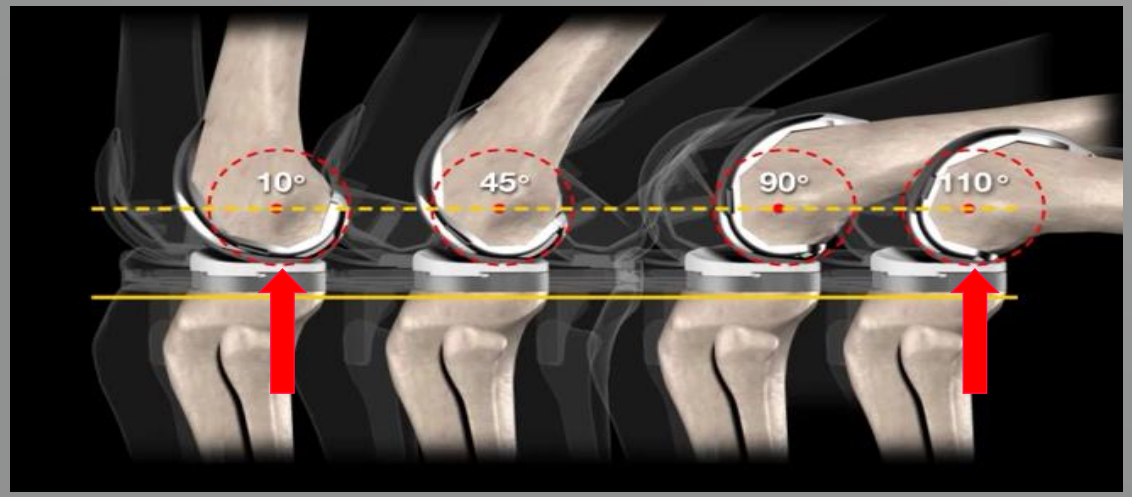
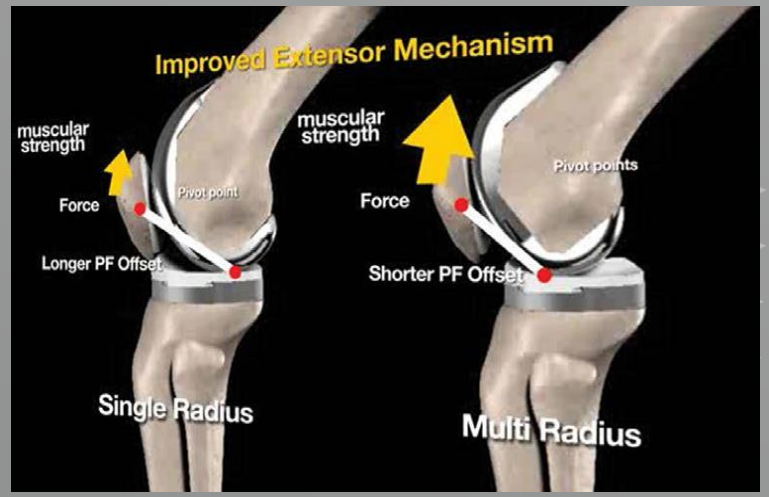


Multi Radius vs Single Radius

- Only difference is in the radius of the femur: multi vs single.
- Single radius based on Hollister's finding of a single epicondylar axis.
- Claimed benefit of single radius:
  - maintaining constant tension on collaterals which would increase stability in mid-flex.
  - Improved Quadriceps moment arm

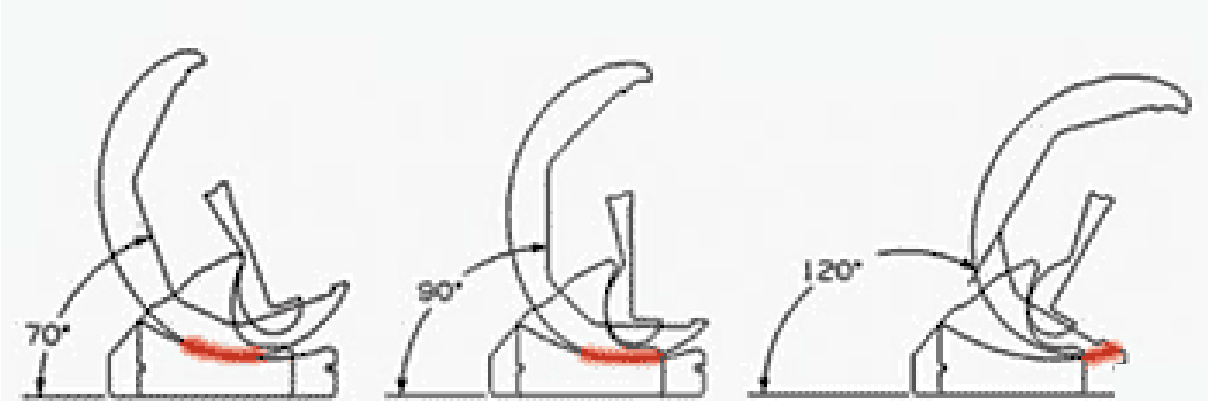
- HOWEVER BOTH DESIGNED FOR SYMMETRICAL ROLL BACK





Kinematic goals of J-curve and single radius knees

- Symmetric movement pattern on both condyles
- Rolling back to posterior edge of tibia from extension to flexion
- Roll back mechanism:
  - CR : tensioning of the PCL with increasing flexion
  - PS : Post-Cam engagement as of a certain degree of flexion



Kinematic issues of rollback knees

Victor et all, 2009 :

- In the normal knee**, motion is guided by surface geometry.**
- **Designed for symmetric roll back**, leading to **Post Cam Conflict** with the natural kinematics of the knee.
- **Forward sliding** of the femur.

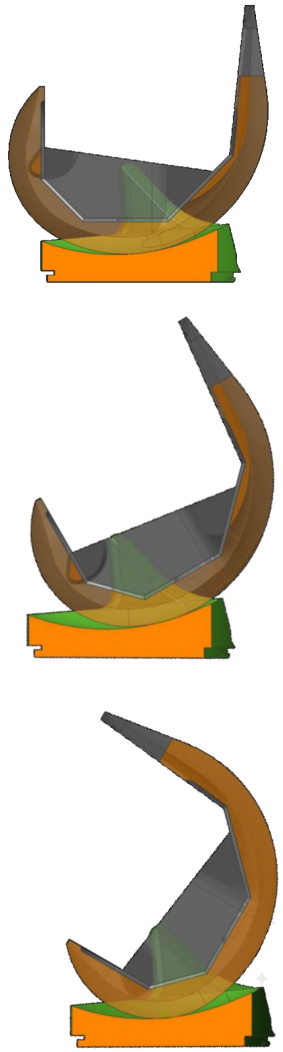
Symmetric knee designs lack the surface geometry and surface match to provide guided motion

ANTERIOR-POSTERIOR INSTABILITY

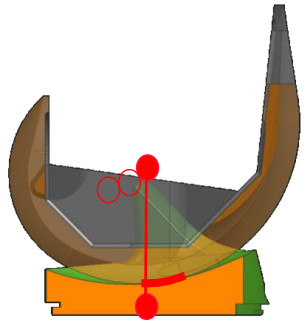
Instability as a design consequence

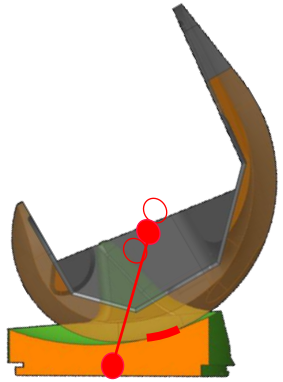
- Don’t confuse ML instability with AP instability
- ML instability causes
  - Malpositioning and malrotation
  - Unbalanced soft tissues
- AP instability is a consequence of missing AP constraint mechanism
  - CR-knees : slack PCL in extension and early flexion
  - PS-knees : Post & Cam only engages at a certain degree of flexion
  - Severely enhanced if not balanced (‘tight’)

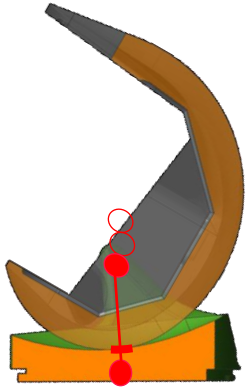
AP Slide



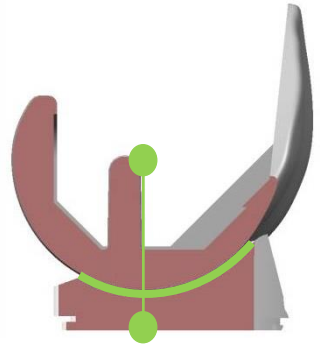
PS versus Medial-Pivot

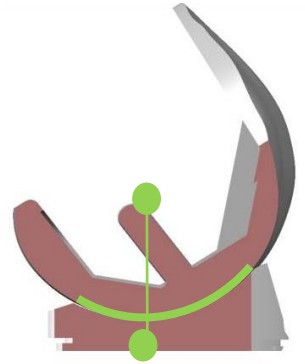


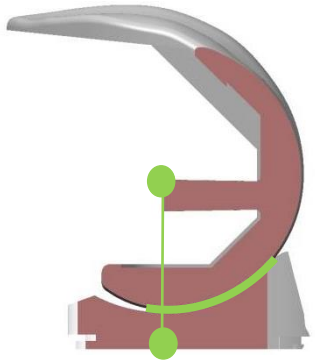




Posterior Stabilized	Medial Pivot
• Round on flat congruency • Small contact area	• Full congruency • Optimal contact area
• Anterior slide of COR till post-cam engagement • Reduction of contact area due to reduced radius	• Stable COR position • Full congruency and optimal contact area
• Post-cam drive rollback • Minimal contact area	• COR in stable position • Small loss contact area







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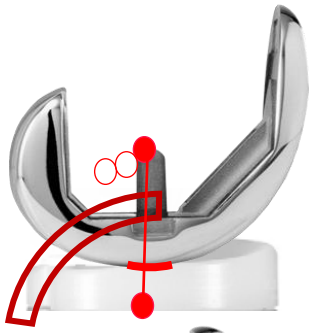
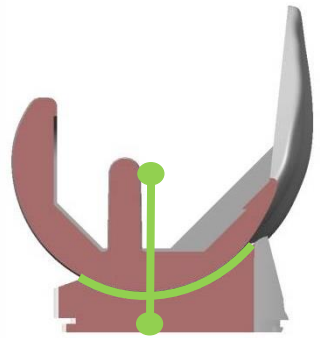
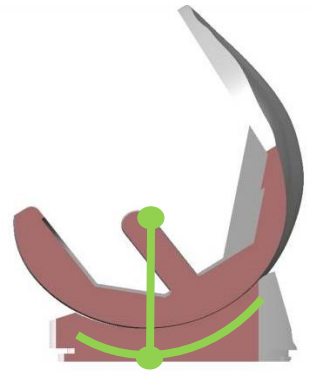
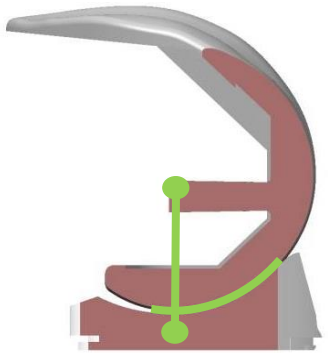
CR versus Medial Pivot



Cruciate Retaining	Medial-Pivot
• Round on flat congruency • Small contact area • PCL relaxed	• Full congruency • Optimal contact area
• Anterior slide of COR till PCL is tight • Reduction of contact area due to lack of congruency	• Stable COR position • Full congruency and optimal contact area
• PCL pulls femur in rollback • Minimal contact area	• COR in stable position • Small loss contact area







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Medial Pivoting Kinematics in the natural knee

Latest Generation:

Medial-Pivoting Kinematics (late 90's -2000):

THE JOURNAL OF BONE & JOINT SURGERY (BJ)

Tibiofemoral movement 1: the shapes and relative movements of the femur and tibia in the unloaded cadaver knee

H. Iwaki, V. Pinskerova, M. A. R. Freeman

From the Charles University, Prague, Czech Republic

THE JOURNAL OF BONE & JOINT SURGERY (BJ)

Tibiofemoral movement 2: the loaded and unloaded living knee studied by MRI

P. F. Hill, V. Vedi, A. Williams, H. Iwaki, V. Pinskerova, M. A. R. Freeman

From St. Mary's Hospital, London and the Royal Hospital, Haslar, England

THE JOURNAL OF BONE & JOINT SURGERY (BJ)

Tibiofemoral movement 3: full flexion in the living knee studied by MRI

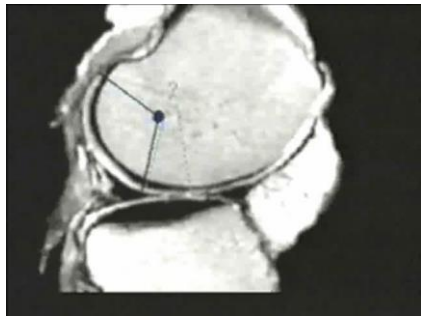
S. Nakagawa, Y. Kadoya, S. Todo, A. Kobayashi, H. Sakamoto, M. A. R. Freeman, Y. Yamano

From Osaka City University and the Sakamoto Orthopaedic Clinic, Osaka, Japan

Conclusion:

- ***The medial side stays stable.***
- ***The lateral side moves anterior and posterior to accommodate rotation.***

Medial Compartment



Lateral Compartment

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Other kinematic findings

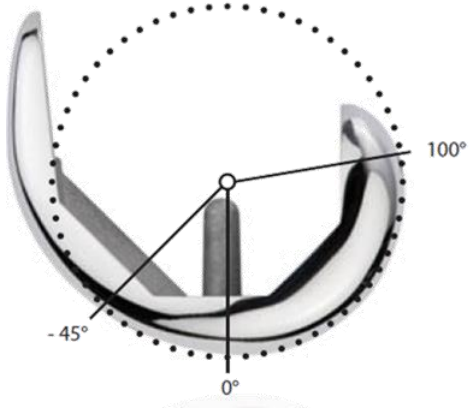
Author	Flexion Range	Medial	Lateral
Pinskerova[6]	0°-110°	Stable	13mm
Nakagawa[7]	90°-133°	2mm	13mm
Johal[8]	90°-120°	3,6mm	22mm

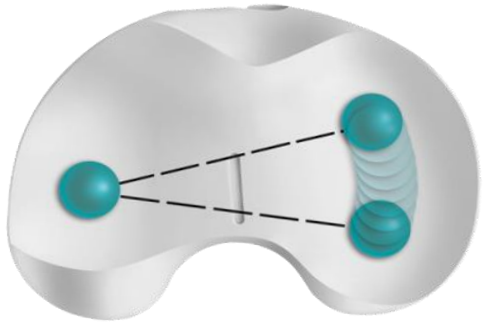
All authors reported significant inter-individual and activity dependent variability, but:

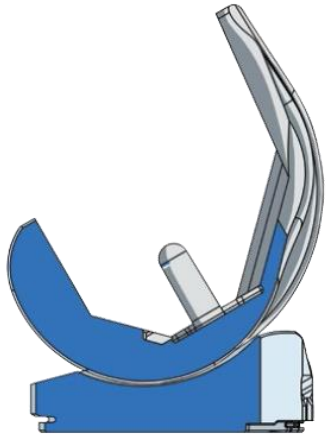
- Relative stability on the medial aspect
- Roll back on the lateral aspect

Medial-Pivot Knee design goals

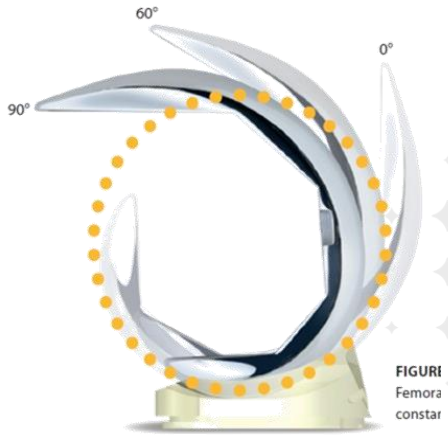
- Replicate or mimic the kinematics of the natural knee
  - **Medial stability**
  - **Lateral freedom allowing roll back**
- Distinctive design features that contribute to this:
  - S**ingle radius femur** complying with the natural single axis
  - Asymmetric **‘ball-in-socket’** insert design
    - Medial: Congruent socket design matching the femoral radius
    - Lateral: Less congruent path allowing 15° of internal/external rotation around the medial pivot point







Medial section of the eMP™ Knee flexed at 30°



FIGURE
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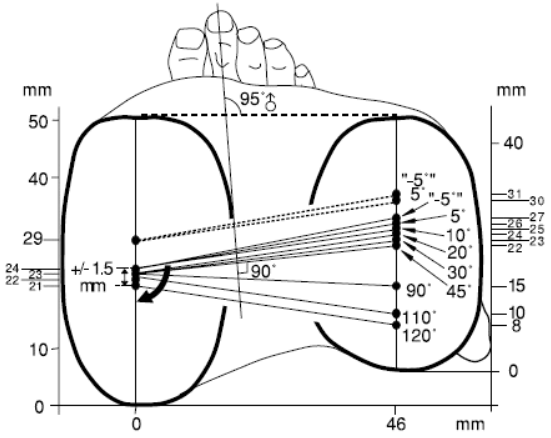
Medial-Pivot Knee design goals

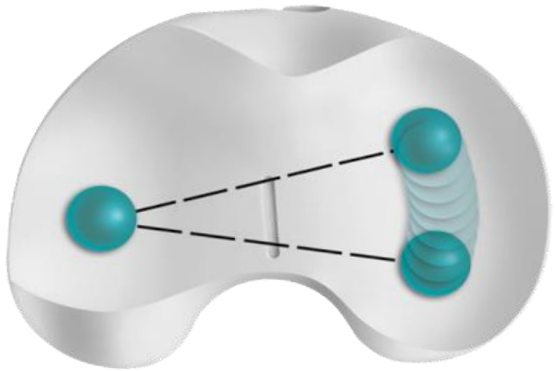
Medial-Pivoting Kinematics

- The medial side stays stable.
- The lateral side moves anterior and posterior to accommodate rotation.

Medial-Pivot Knee:

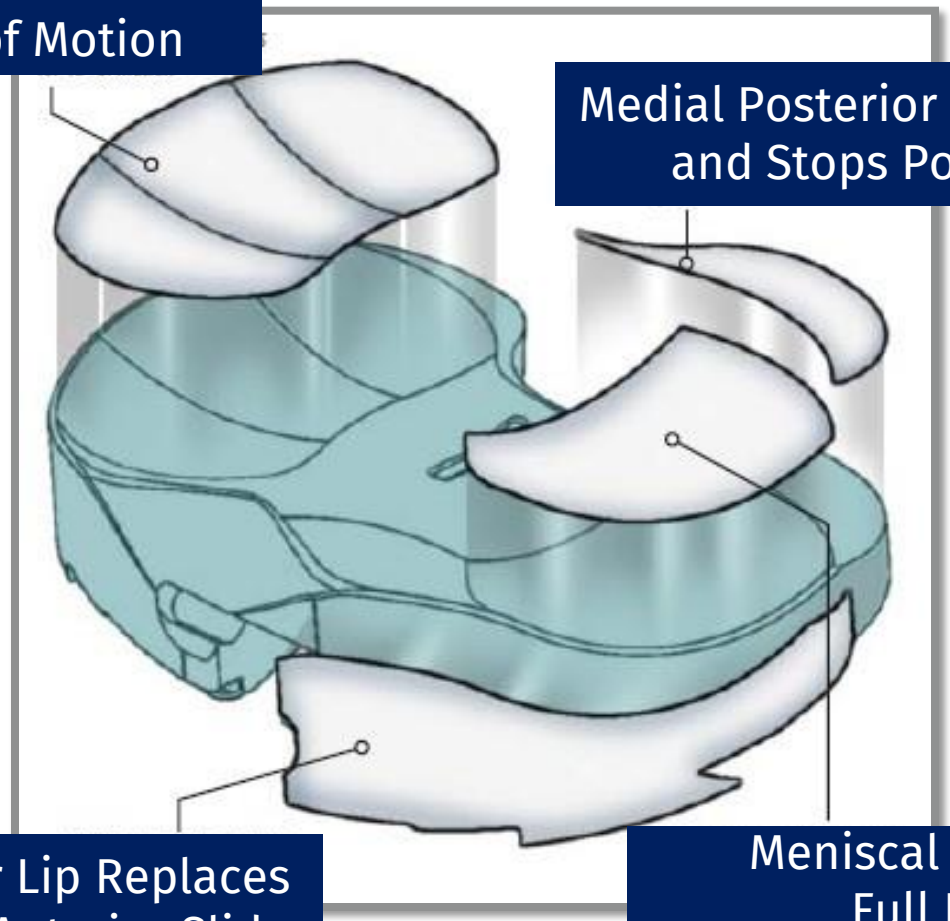
- Advance® Knee System first to market Medial-Pivot Knee design, launched in 1998.
- Evolution® Knee System, second generation design, launched in 2010.





The Key to guided medial pivoting motion: Medial-Pivot Insert

Lateral Meniscal Path
Allows 15° of Motion



Medial Posterior Lip Replaces ACL
and Stops Posterior Slide

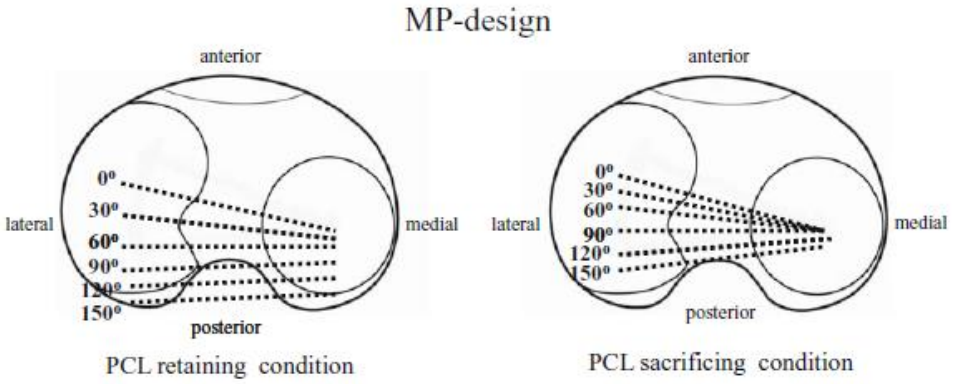
Medial Anterior Lip Replaces
PCL and Stops Anterior Slide

Meniscal “Socket” Provides
Full ROM Stability

Evolution® CS = Cruciate Substituting

A Medial-Pivot knee sacrifices both Cruciate Ligaments (ACL & PCL)

Omori[9]



Vecchini[10]

PCL retained : The mean ROM was improved from 97.7° to 112.5°

PCL sacrificed : The ROM improved from 93.35° to 120.5°

Kinematic Matrix

Extension to flexion	Medial	Lateral	MCL tension	Q lever arm	In Vivo Kinematics
Multi radius CR & PS	Roll back	Roll back	Decreasing	Weak	AP slide
Single radius CR & PS	Roll back	Roll back	Constant	Strong	AP Slide
Medial Pivot	Stable pivot	Roll back	Constant	Strong	Medial Pivot
Natural knee	Stable pivot	Roll back	Constant	Strong	Medial Pivot

AP Stability Matrix

Stability	Mechanism	Engagement	Jump resistance	Instability
CR knees	PCL tension	Mid to deep flexion	PCL	Early to Mid flex
PS Knee	Post Cam engagement	Design dependent	Post height & width	Early to Mid flex
Medial Pivot	Medial Ball in Socket	Full ROM	Anterior lip	None
Natural knee	ACL+PCL	Full ROM	PCL	None

Sagittal Stability

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