



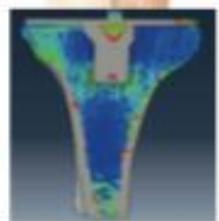
PROTHÈSES TOTALES DE GENOU

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Cahiers d'enseignement de la SOFCOT
Collection dirigée par Denis Huten



Prothèses totales de genou



Coordination :
Sébastien Lustig
Sébastien Parratte

ELSEVIER

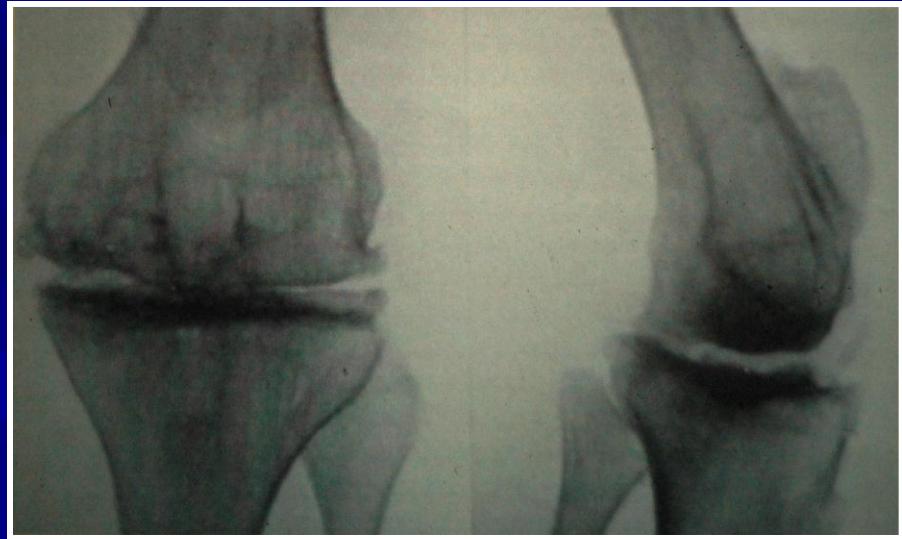
Elsevier Masson

Un peu d'histoire ...



Tissu autologue d'interposition (fascia-lata, graisse)

- BARTON: 1826
- FERGUSSON: 1851
- MURPHY: 1913
- PUTTI: 1920
- ALBEE: 1928
- KUHAN et POTTER: 1950 (nylon)

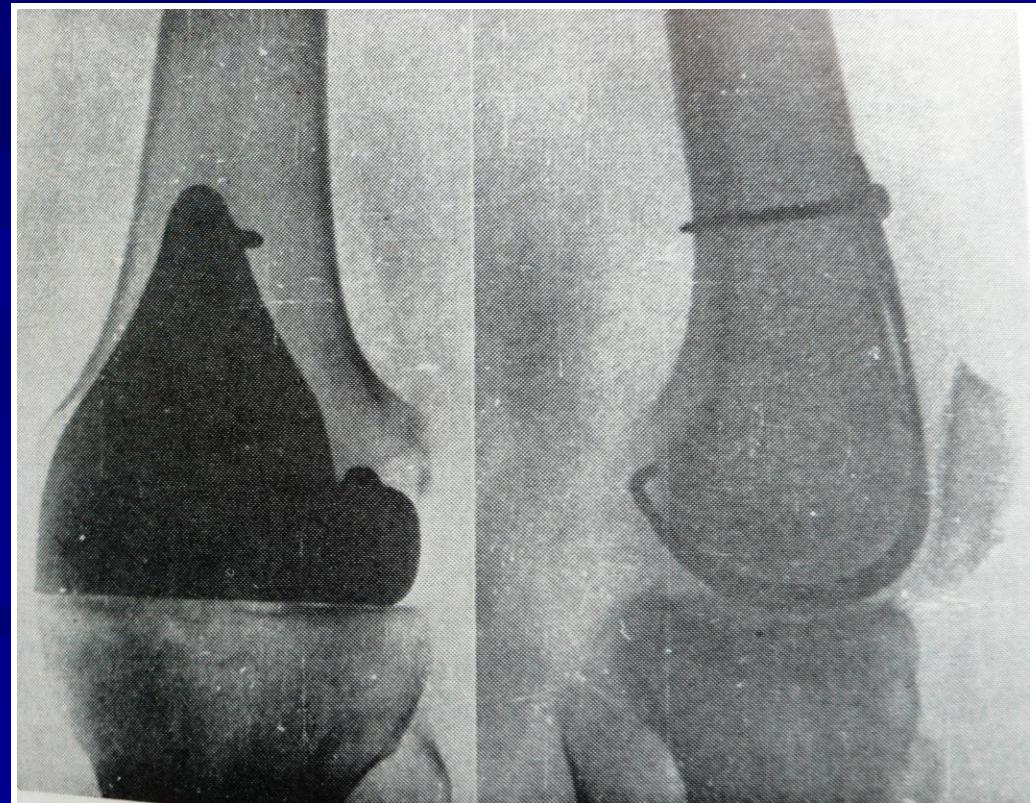
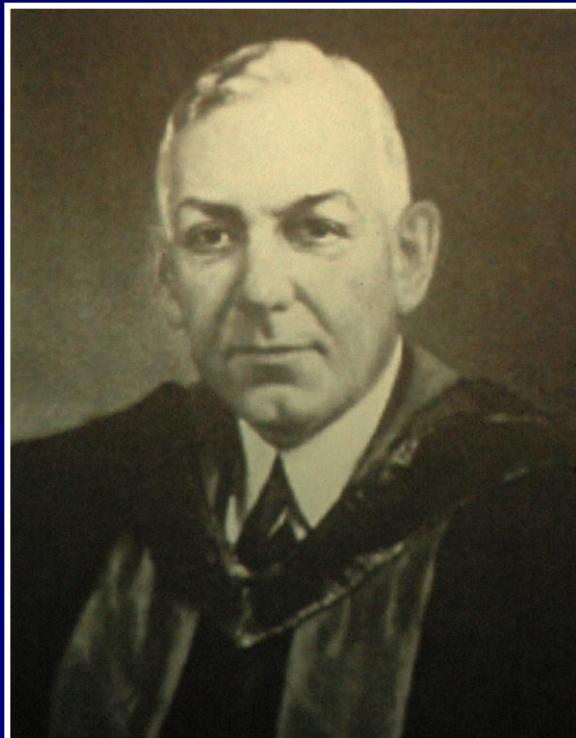


Prothèses partielles (Fémorale)

CAMPBELL et BOYD : 1938

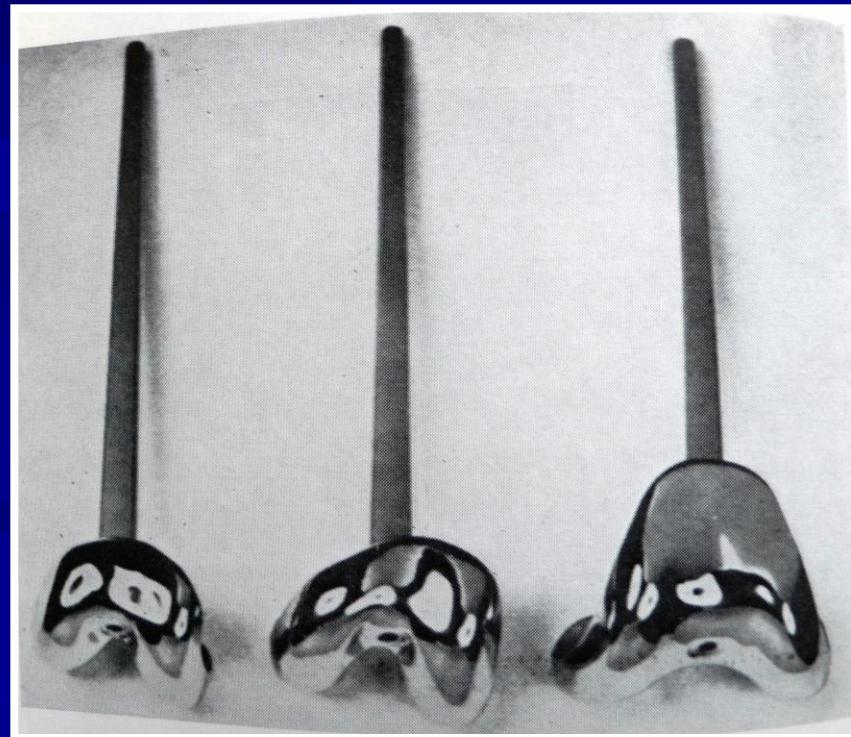
American Academy of Orthopaedic Surgery

- Plaques de vitallium moulées sur les condyles



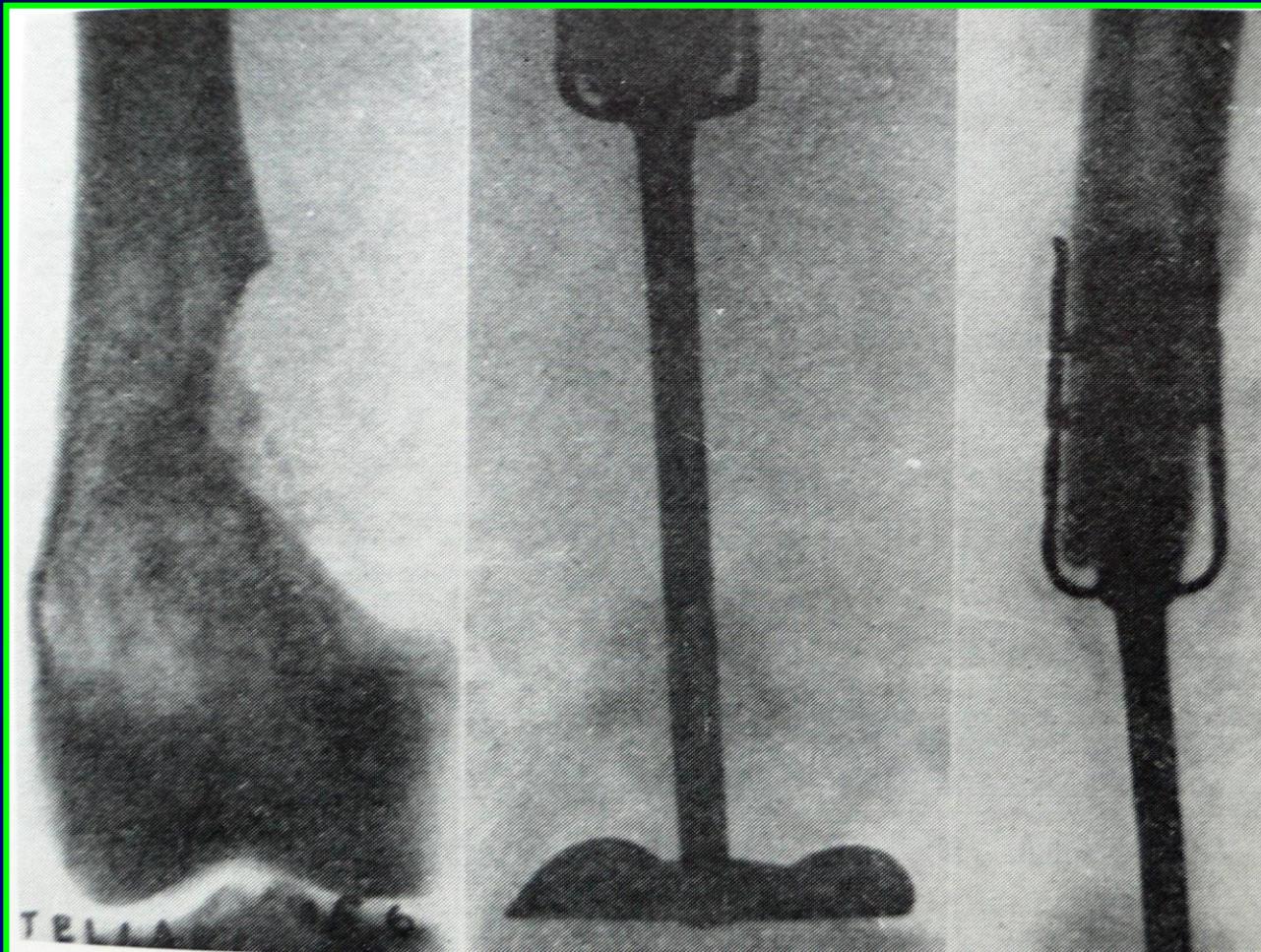
SMITH-PETERSEN

- 1940 Premier modèle: moule condylien mobile.
- 1950-52 Tige centro-médullaire; évolution vers la M.G.H(Massachusetts General Hospital)

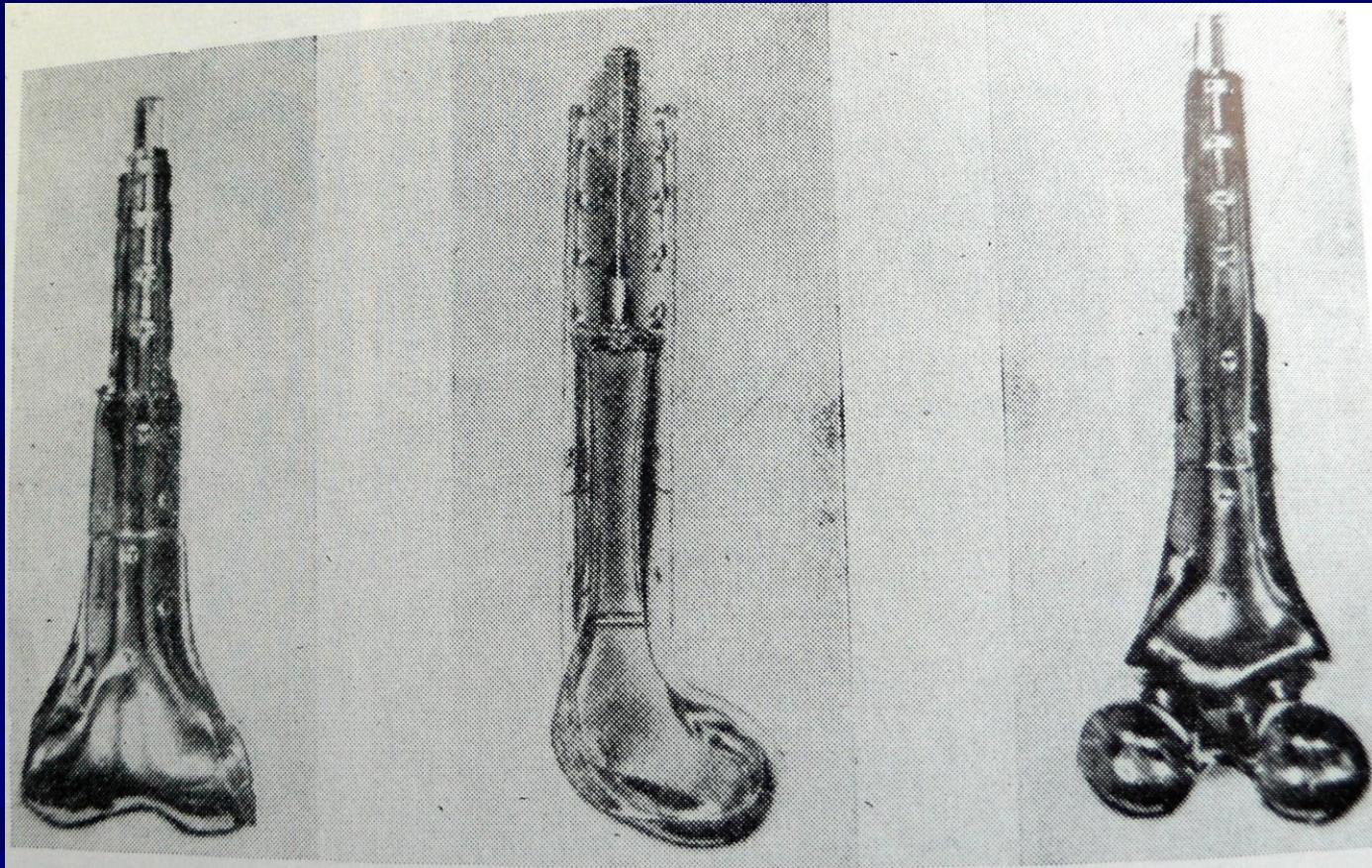


DELITALA 1947

- Endoprothèse fémorale de résection



CABITZA 1950



Echecs septiques ou mécaniques

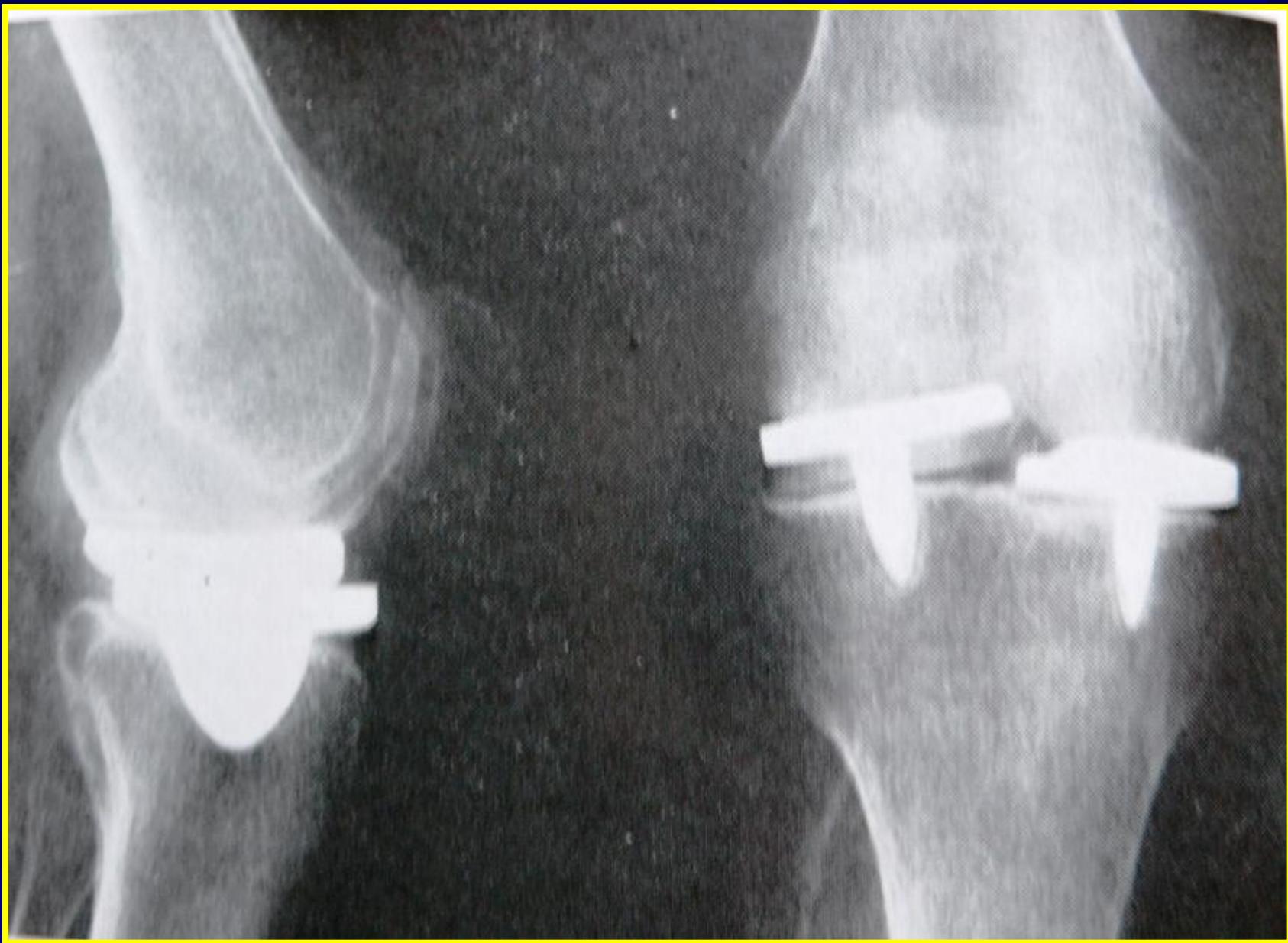
Prothèses partielles (Tibiale)

1944: BURMAN
plateaux vitallium vissés

1950: MAC KEEVER
plateaux vitallium à ailettes

1954: MAC INTOSH
3 tailles; 4 épaisseurs

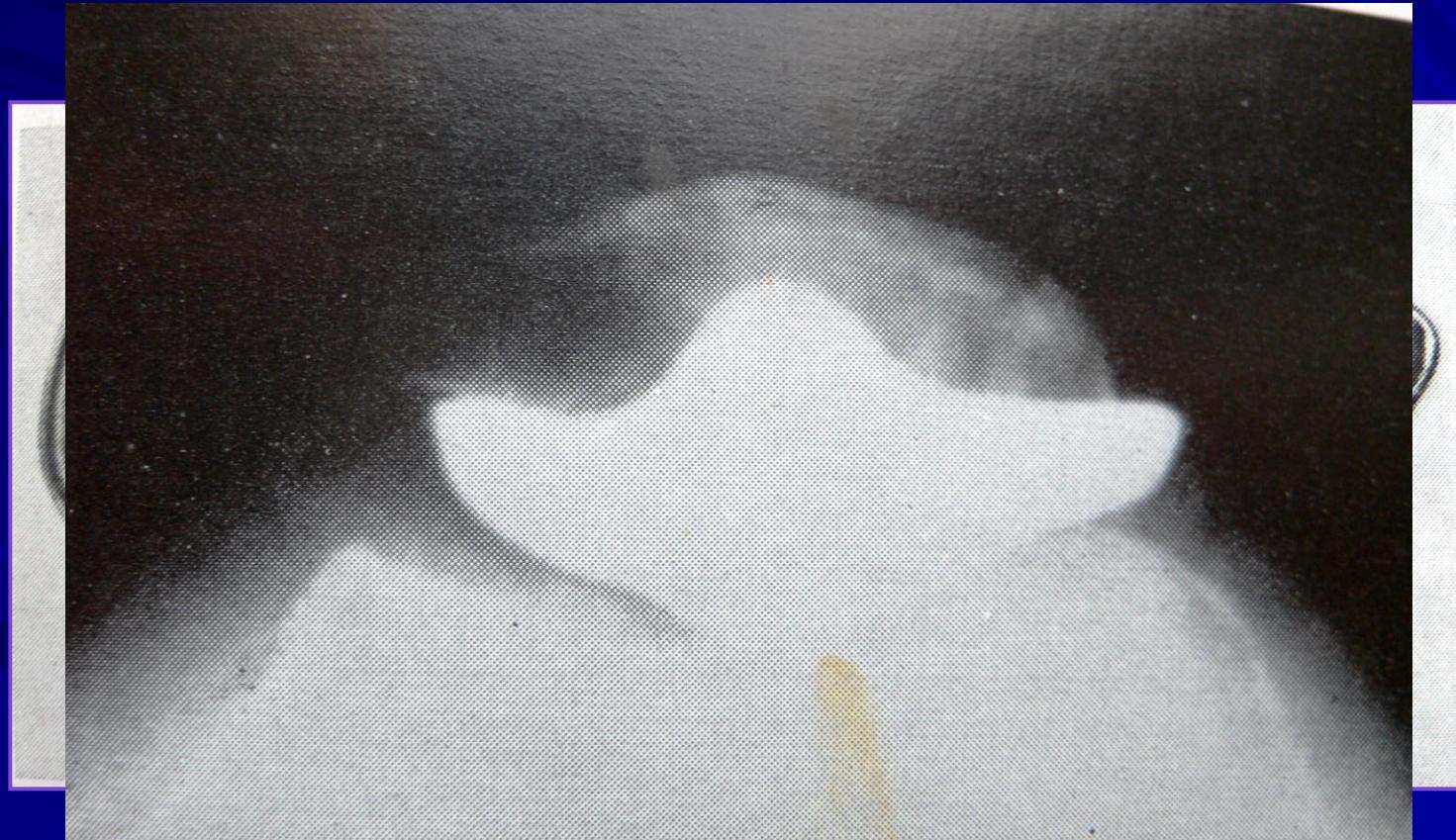
1964: TOWNLEY
plateau unique vissé; respect des croisés



Prothèses partielles (rotule)

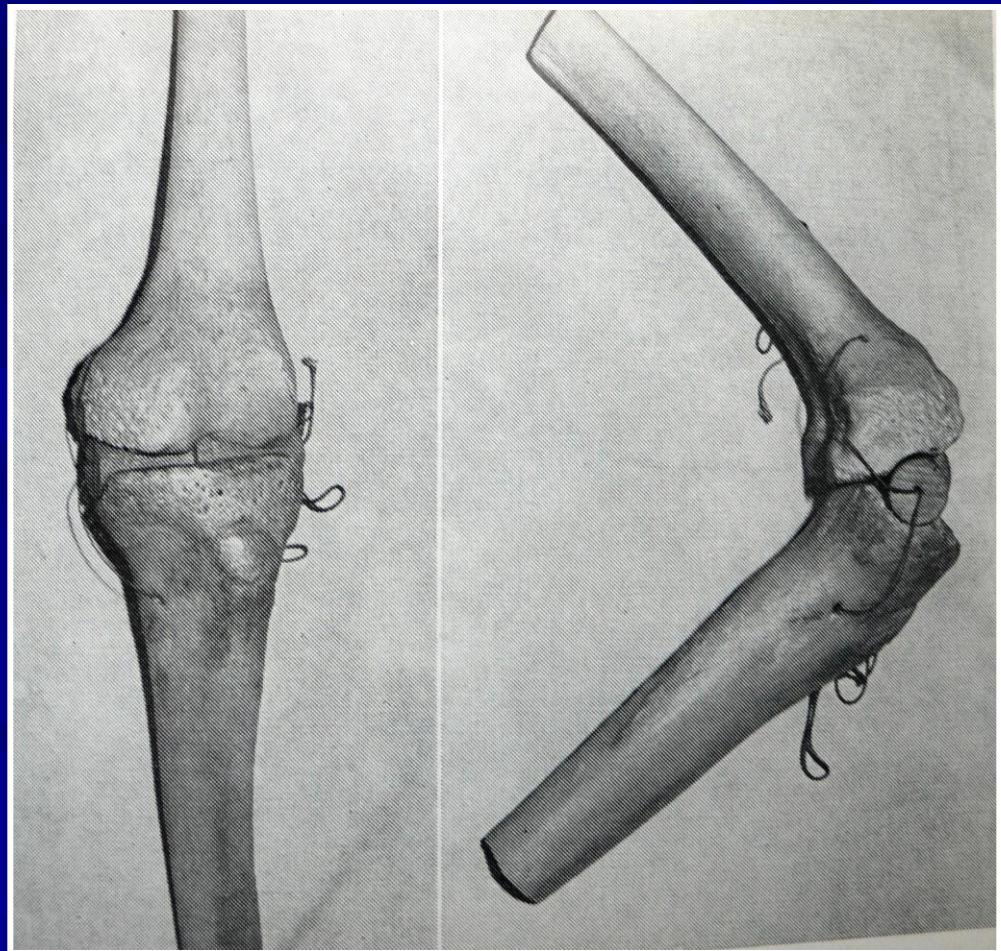
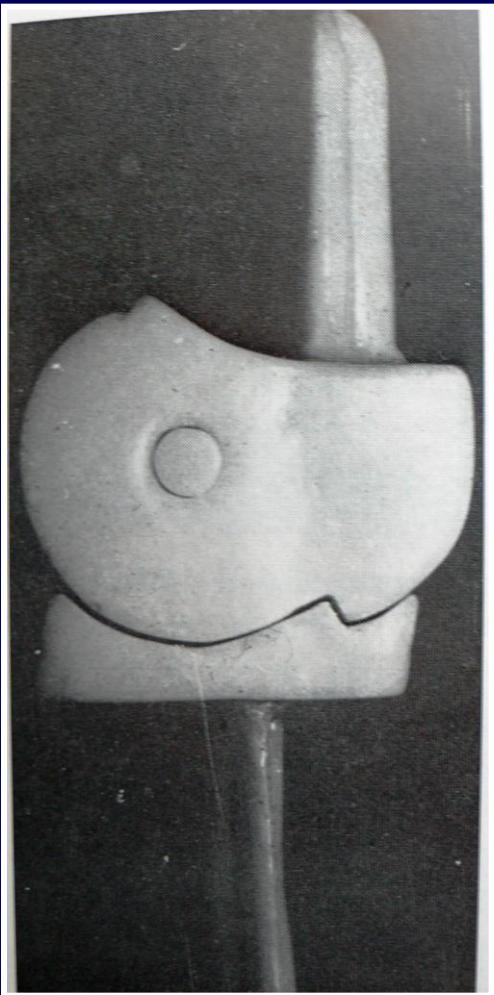
1955: MAC KEEVER

- 1^{er} implant rotulien

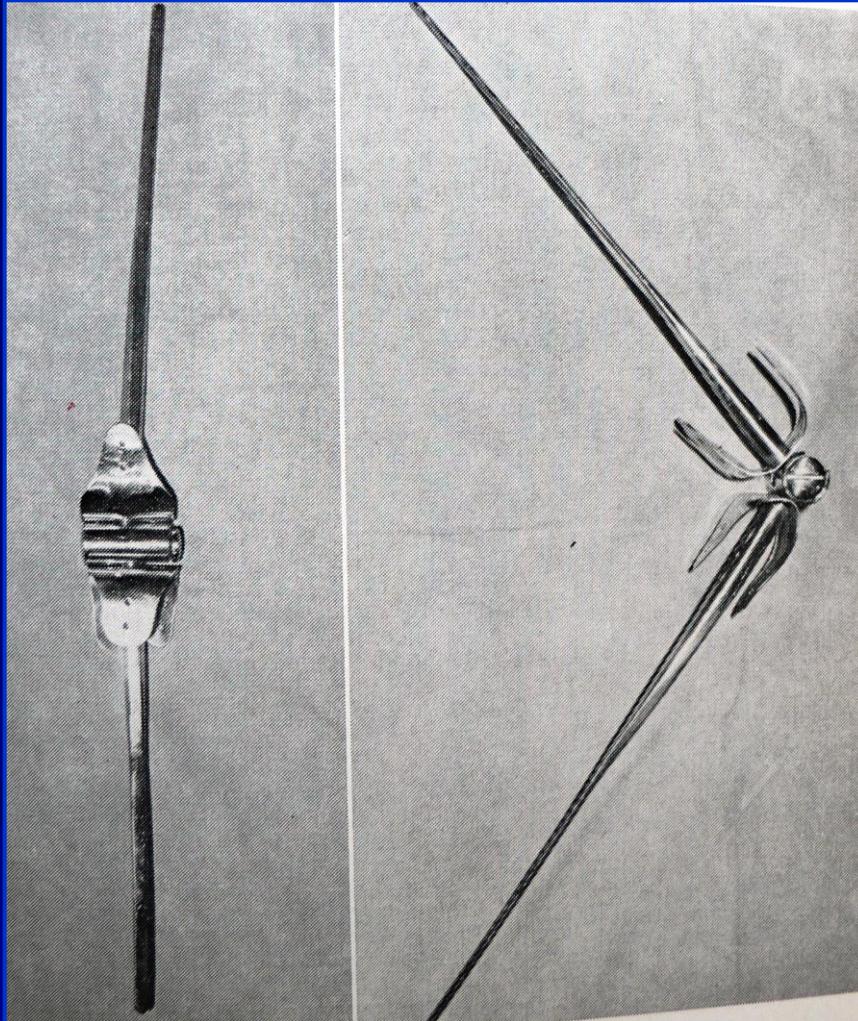


Prothèses totales à charnière

1947: Robert et Jean JUDET
1951: MAJNONI D' INTIGNANO
DIAMANT-BERGER

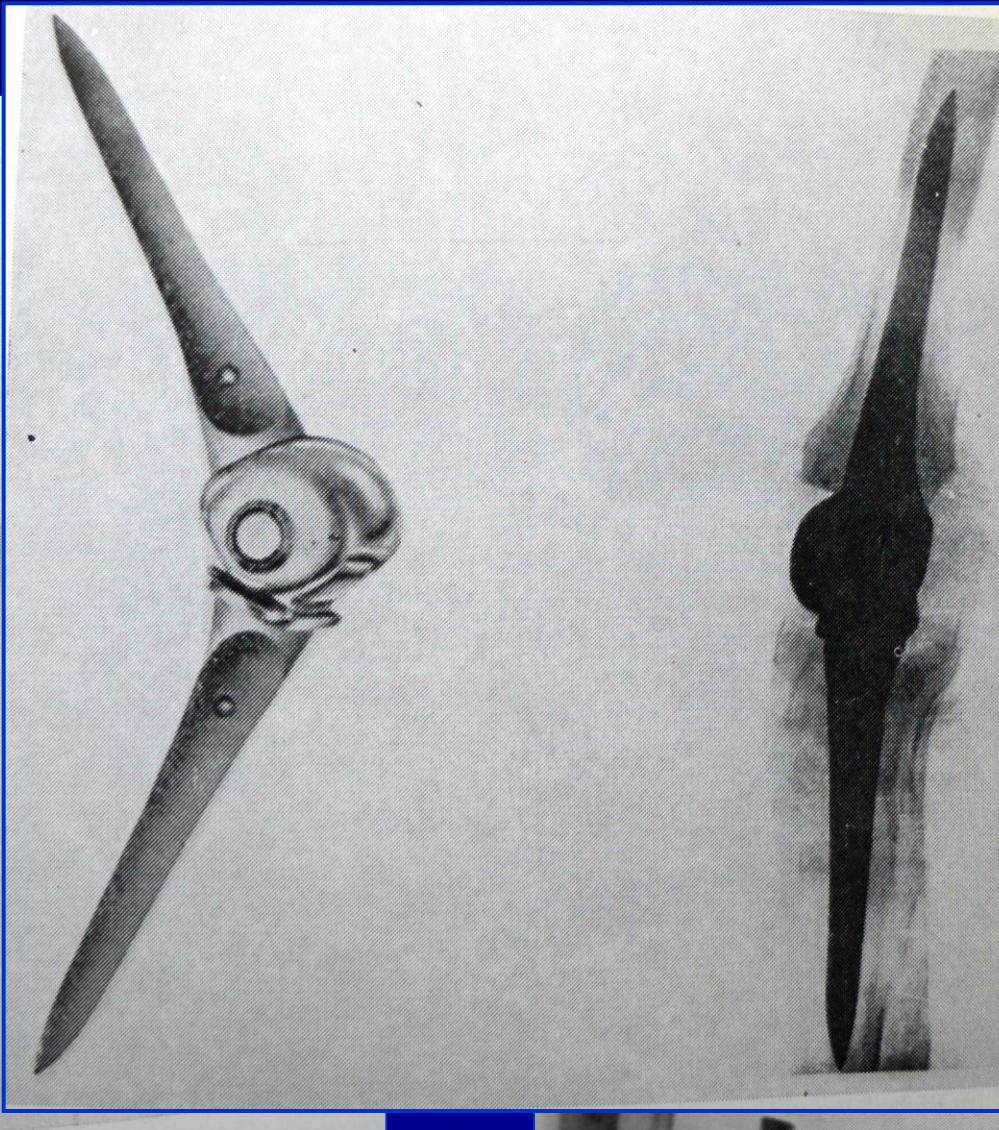
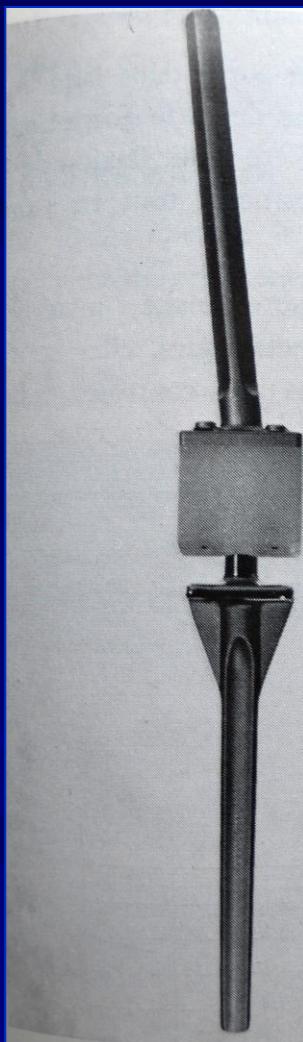


1953: MERLE D'AUBIGNE

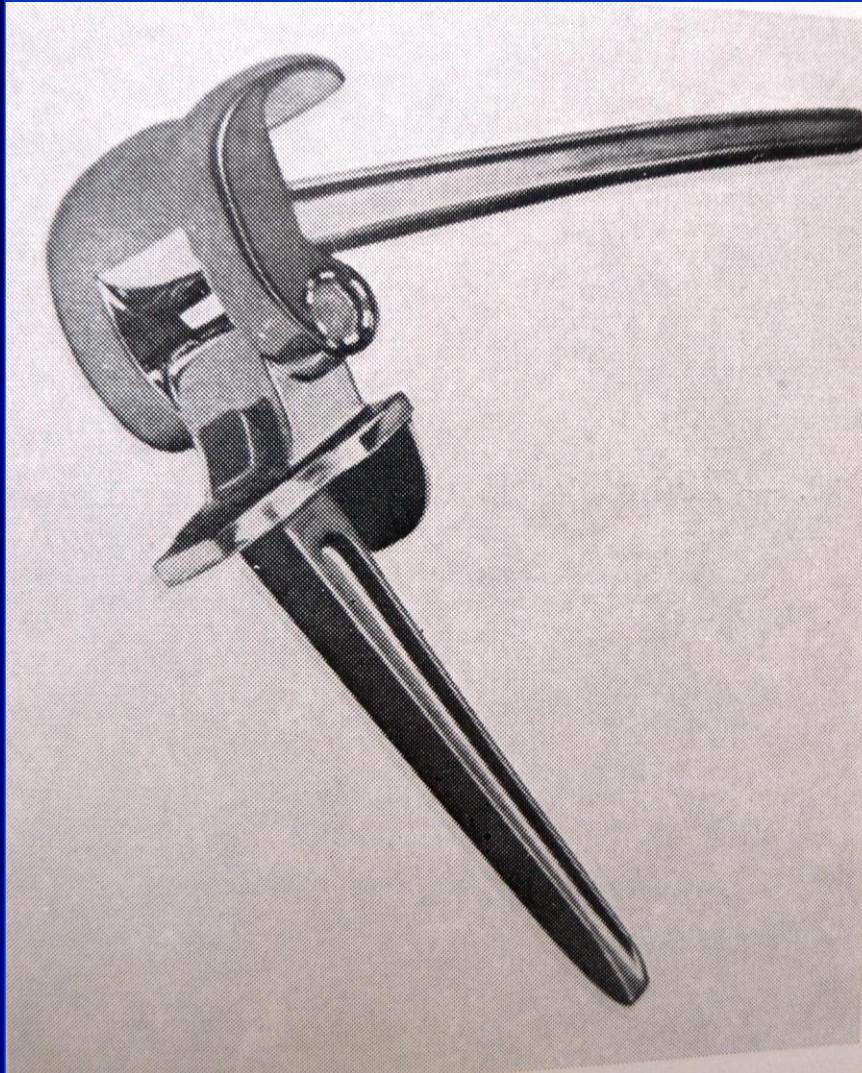


prothèse
« hirondelle »

LagrangeKee Mageketournel

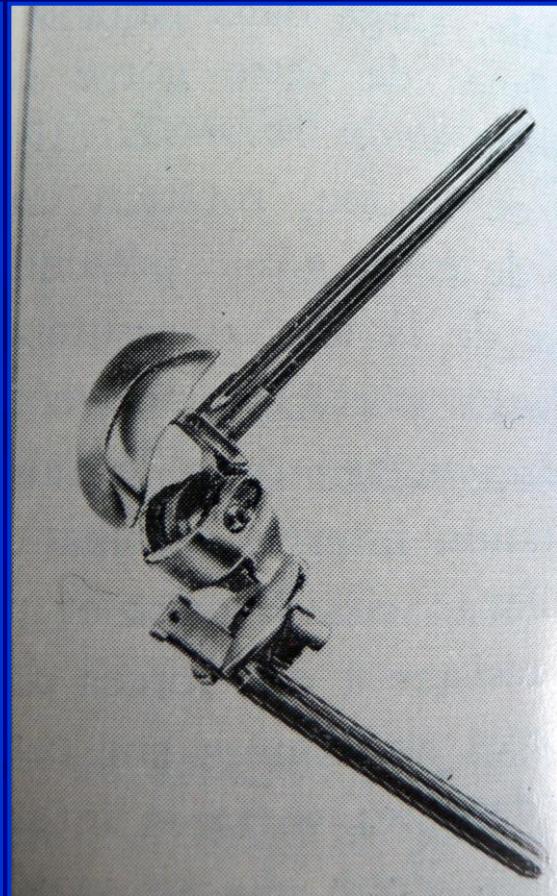
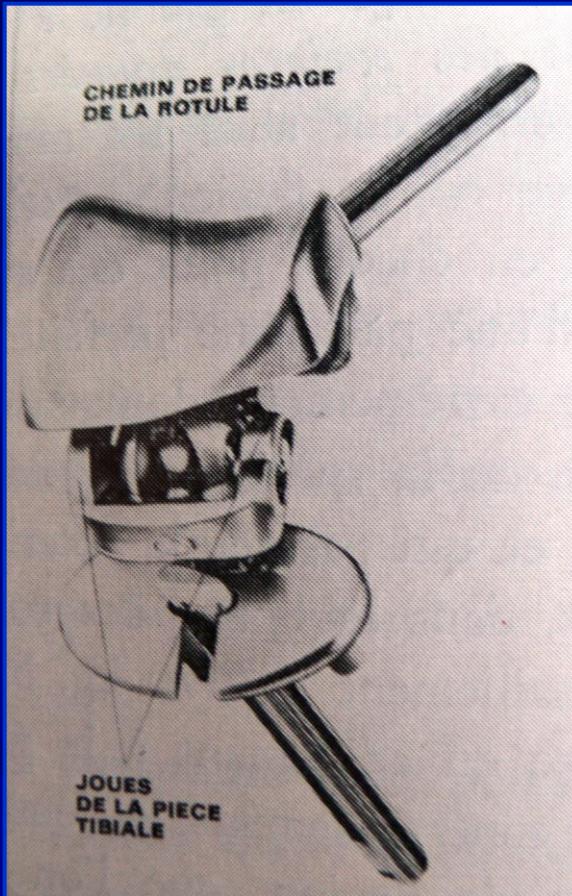
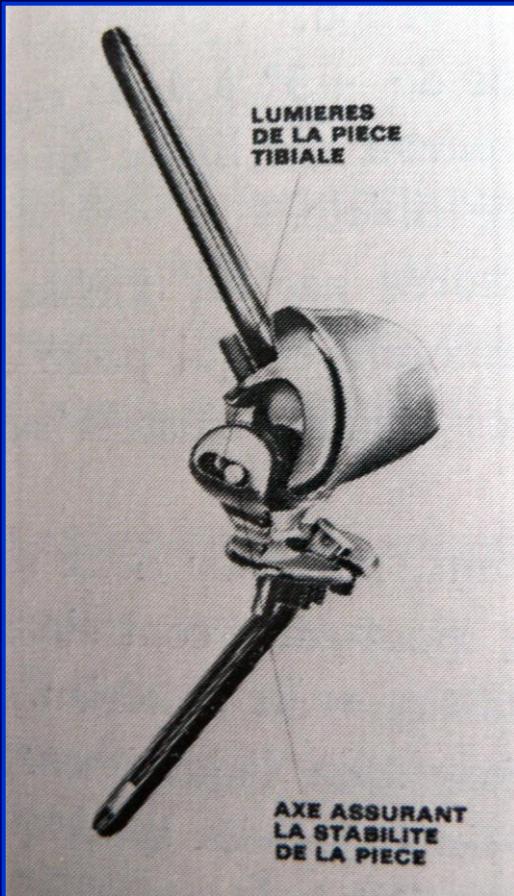


Guépar



Prothèses totales à pivot

1971: BOUSQUET et TRILLAT



Prothèses totales à glissement

1965: GUNSTON

4 pièces

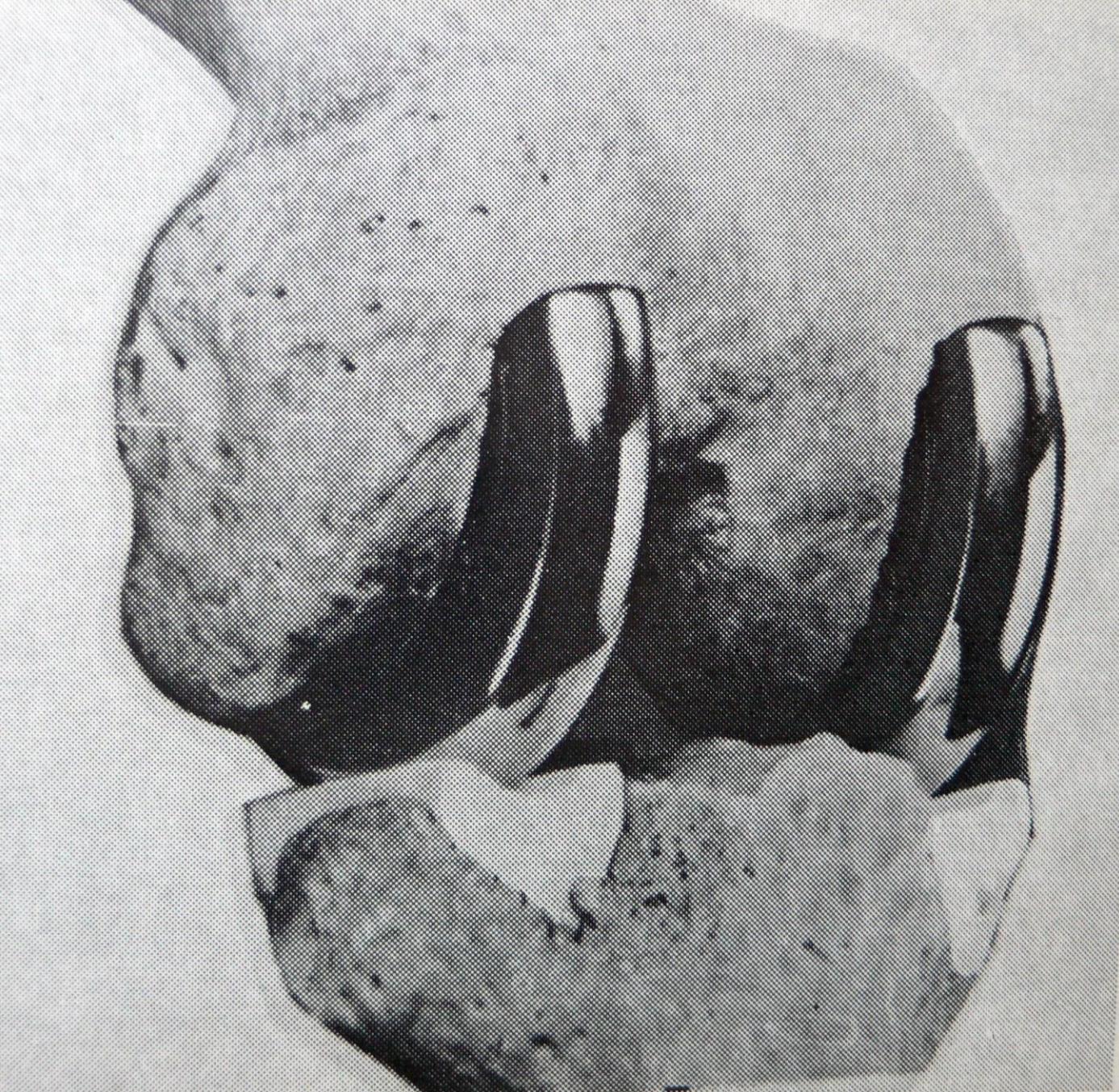
1969: BRYAN PETERSON

Polycentric

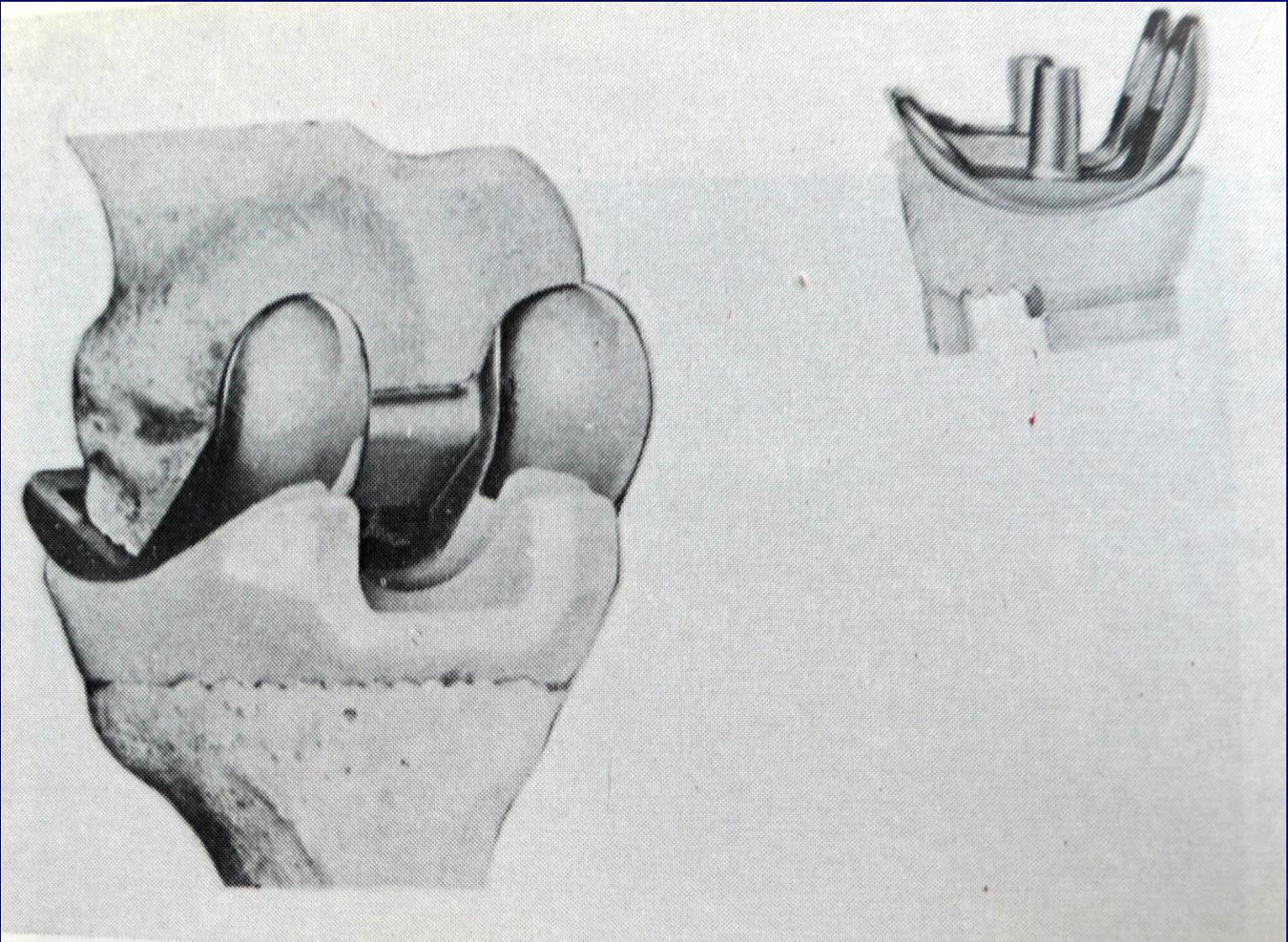
1970: ENGELBRECHT

Trainneau Saint Georg

1973: MARMOR, LOTUS



Polycentric

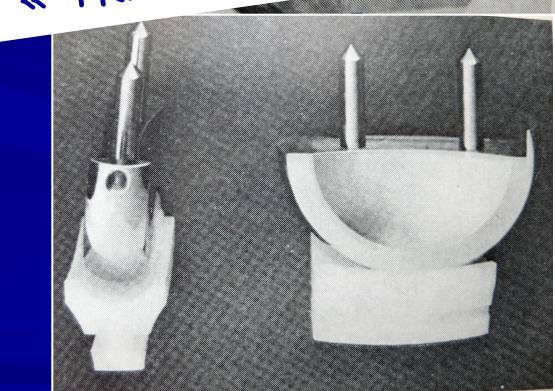


© 2009 Mosby

21 July 1969

BRYAN PETERSON / Polycentric

1st man walking on the moon



« TKA » with only one size !!

PROTHESES NON CONTRAINTEES

→ Conservation du pivot central

Townley 1972

Walker (Kinematic) 1975

Cloutier 1977

Puis PCA, Miller-Galante
Hermes, Goeland...

PROTHESES SEMI- CONTRAINTEES

→ Pas de conservation des croisés

Freeman Swanson	1970
Insall (Total Condylar)	1972
H.L.S.	1984

PROTHESES A SURFACE D'APPUI MOBILE

- Goodfellow → *Oxford knee* (1977)
- Buechel & Pappas → New Jersey (LCS)
- Polysoides & Tsakonas → Rotaglide

LCP

■ Conserver le LCP : intérêt théorique

Maintenir le roll back

Conserver la tension du LCP

■ Sacrifier le LCP :
stabilisation antéropostérieure
par le dessin de la prothèse



Roll-back condylien

■ Mahoney (1994)

- PTG PS : meilleure cinématique ?
- PTG à conservation du LCP :
roll-back excessif / roll-forward ?

Posterior cruciate function following total knee arthroplasty. A biomechanical study. J Arthroplasty 9 : 569-578.

Roll-back condylien

■ Dennis (1994)

- Etude en fluoroscopie
- Déplacement antérieur paradoxal
→ roll-forward

DENNIS D.A., KOMISTEK R.D., COLWELL C.E., RANAWAT C.S., SCOTT R.D., THORNHILL T.S., LAPP M.A. 1998. *In vivo anteroposterior femorotibial translation of total knee arthroplasty: a multicenter analysis.* Clin Orthop 356: 47-57.



Tension du LCP

Après PTG : tension normale ?

Incavo : étude in vitro



30%

(tension physiologique du LCP)

 INCAVO S.J., JOHNSON C.C., BEYNNON
B.D., HOWE J.G. 1994. *Posterior cruciate ligament strain biomechanics in total knee arthroplasty*. Clin Orthop Relat Res. 309: 88-93.

Cinématique de la PS

■ Plateaux hyper-congruents (« deep dished »)

Pas de roll-back

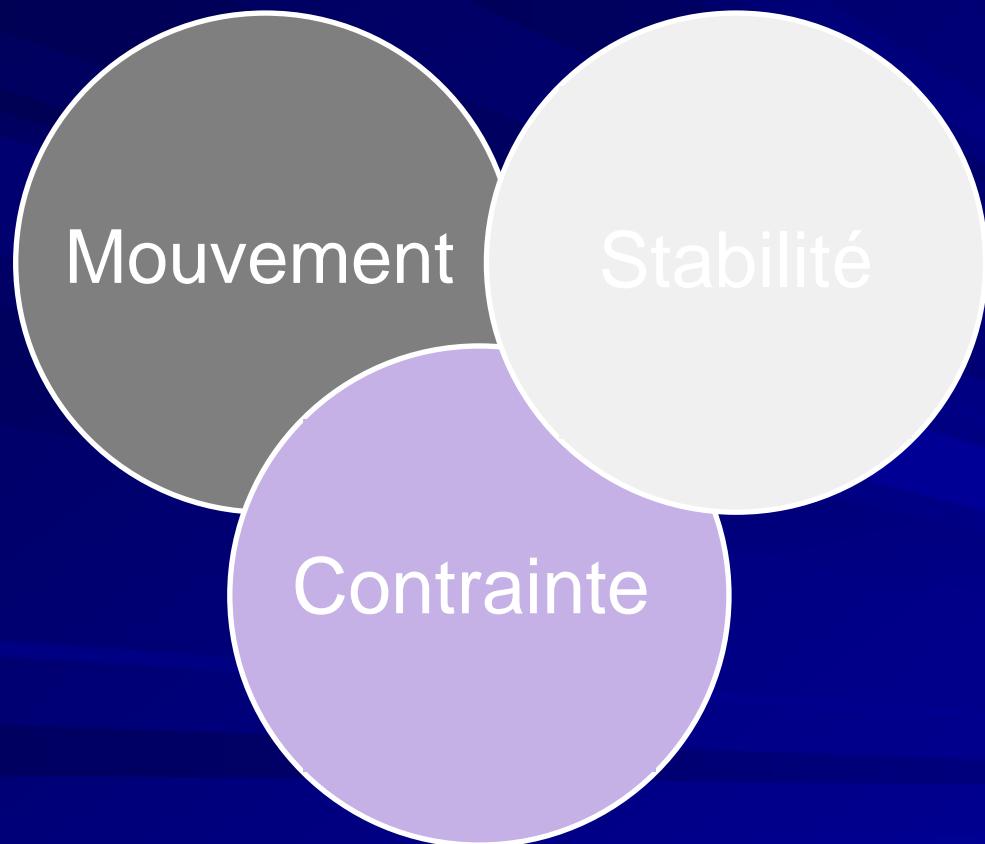


Cinématique de la PS

- Came fémorale postérieure / plot tibial



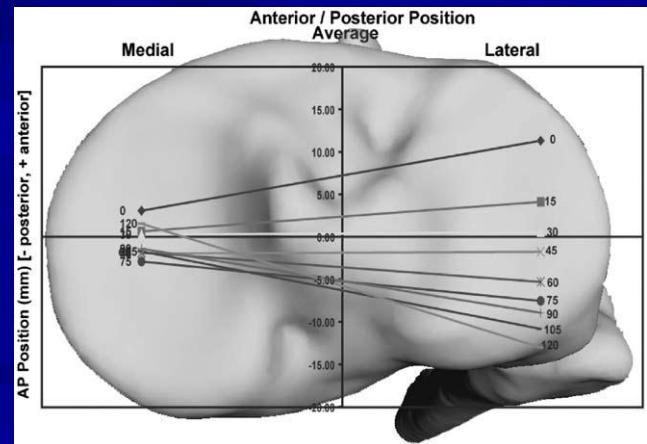
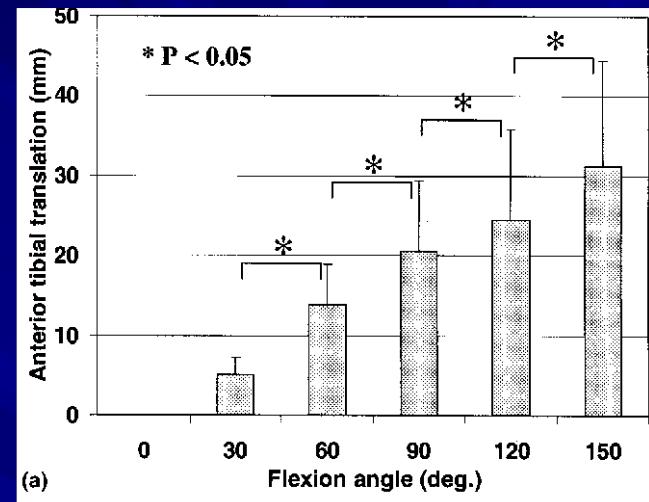
Les effets de la Came de postéro stabilisation



1. Mouvement

Biomécanique du genou sain

- Le fémur recule au cours de la flexion: Li -2004- J of Orthop Res
- Le tibia tourne vers l'intérieur en cours de flexion (23° à 120 degrés de flexion Dennis 2005 – J Biomech)



Effets recherchés du système plot-came

- Contrainte ***sagittale*** pour obtenir du « roll-back » avec parfois une contrainte ***horizontale*** rotatoire
- Contrainte ***frontale*** de stabilisation (type CCK)

Le roulement postérieur « Roll Back »

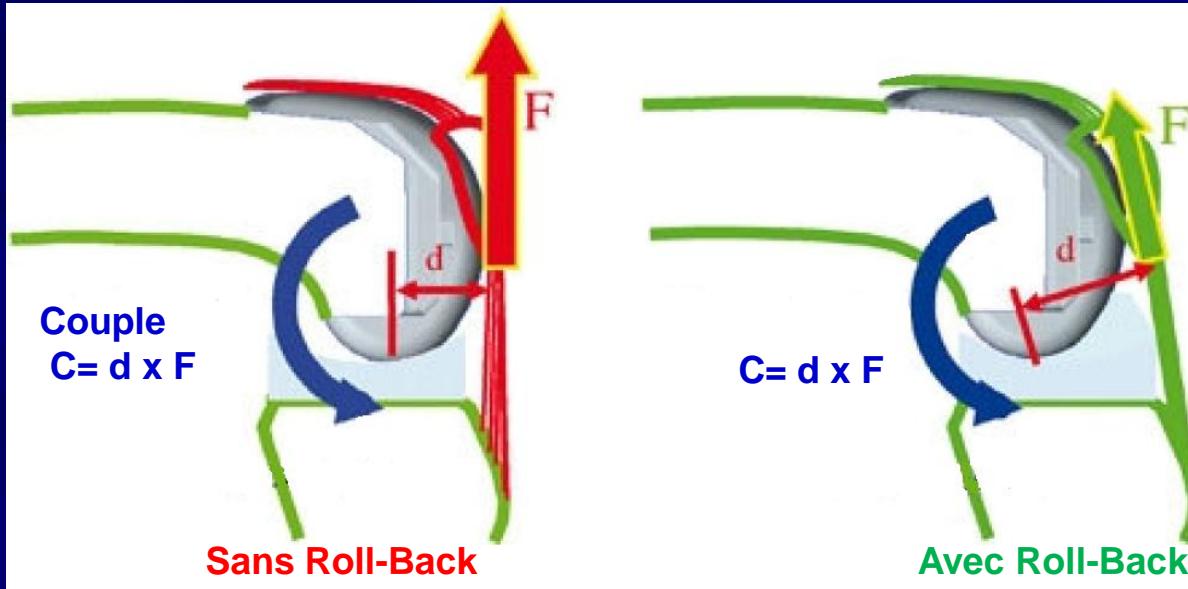
- Produit par l'engagement de la came sur le plot



Prothèse
« Anatomic »
(Courtesy Amplitude
®)

BENEFICES THEORIQUES

Roll-Back = Efficacité du quadriceps



Le roll-back permet d'obtenir un couple identique avec une force quadricipitale moindre (**augmentation du bras de levier**)

- Optimisation de la fonction quadricipitale
- Diminution des contraintes sur l'appareil extenseur
- Diminution des pressions de contacte entre la rotule et la trochlée

Déplacement sagittal

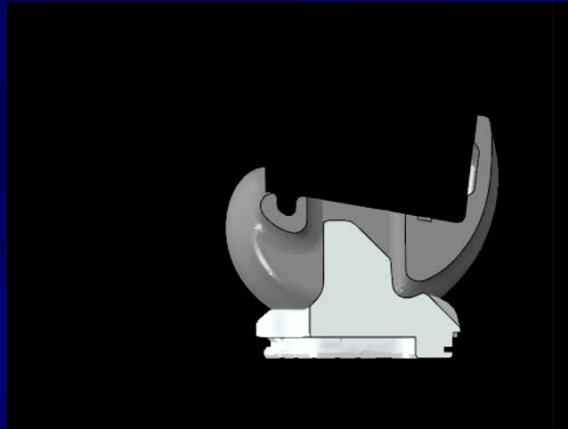


Positions relatives de la came et du plot

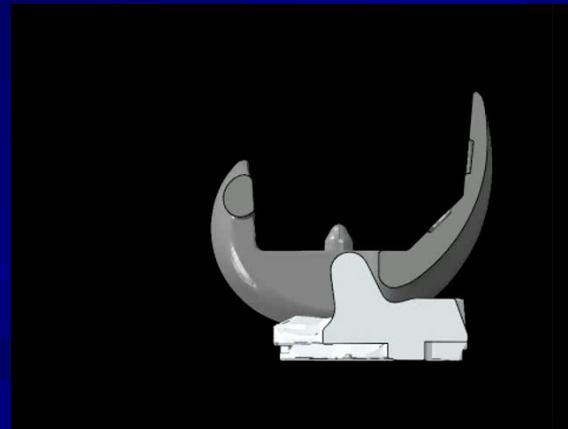
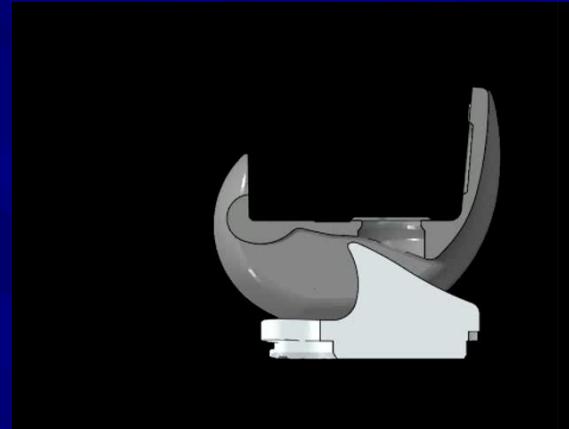
Dessin de la came et du plot

Différents dessins

ATTUNE™
PS FB System

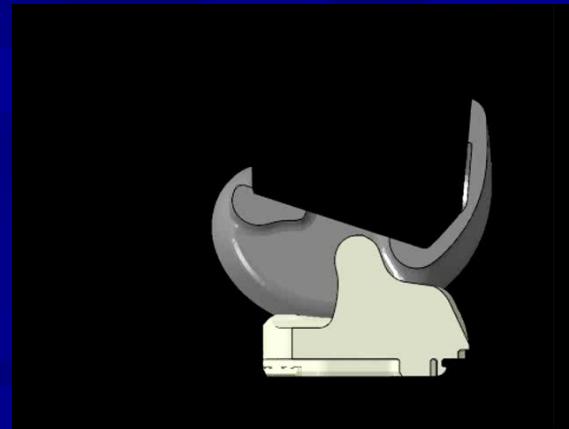


SIGMA®
PS FB System



NexGen®
PS FB System

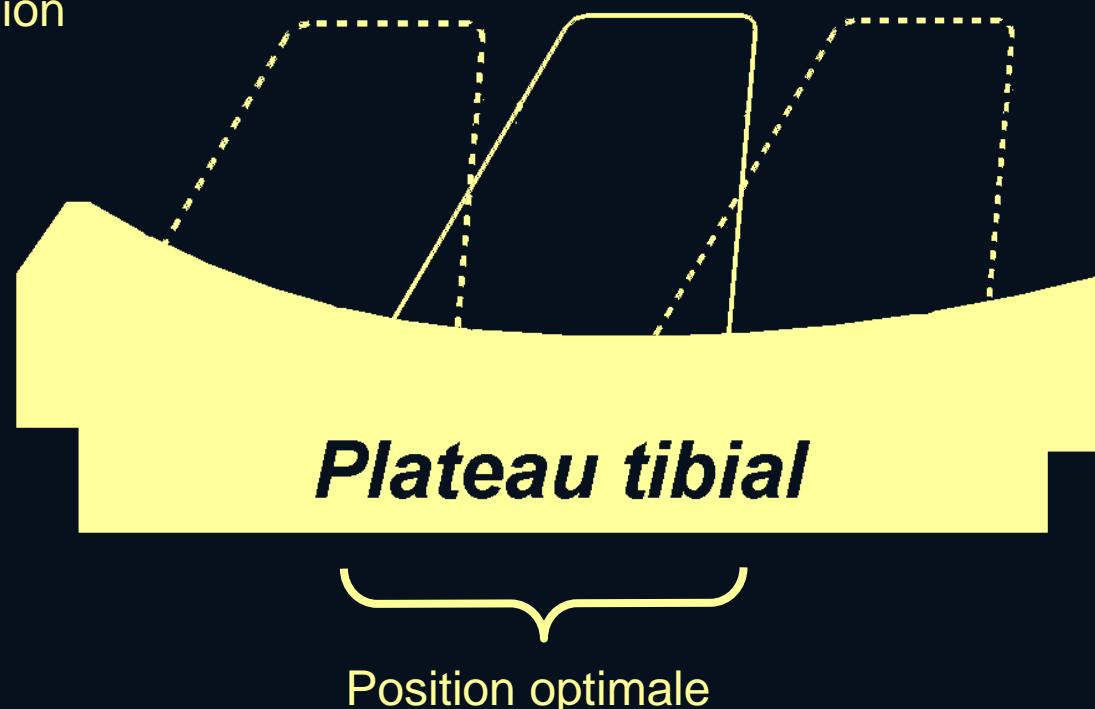
Triathlon®
PS FB System



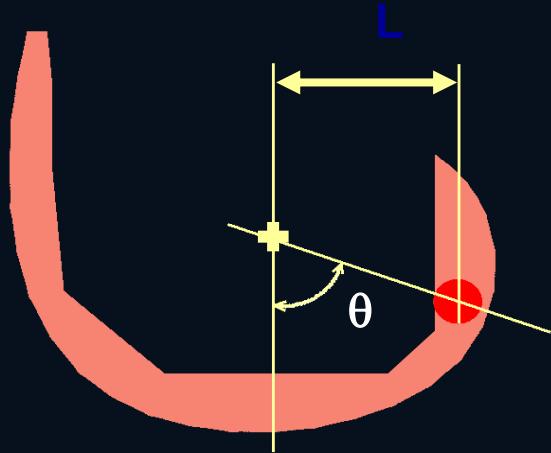
Position du plot ?

Risque de conflit en
hyperextension

Risque de conflit en
flexion extrême



Position de la came ?

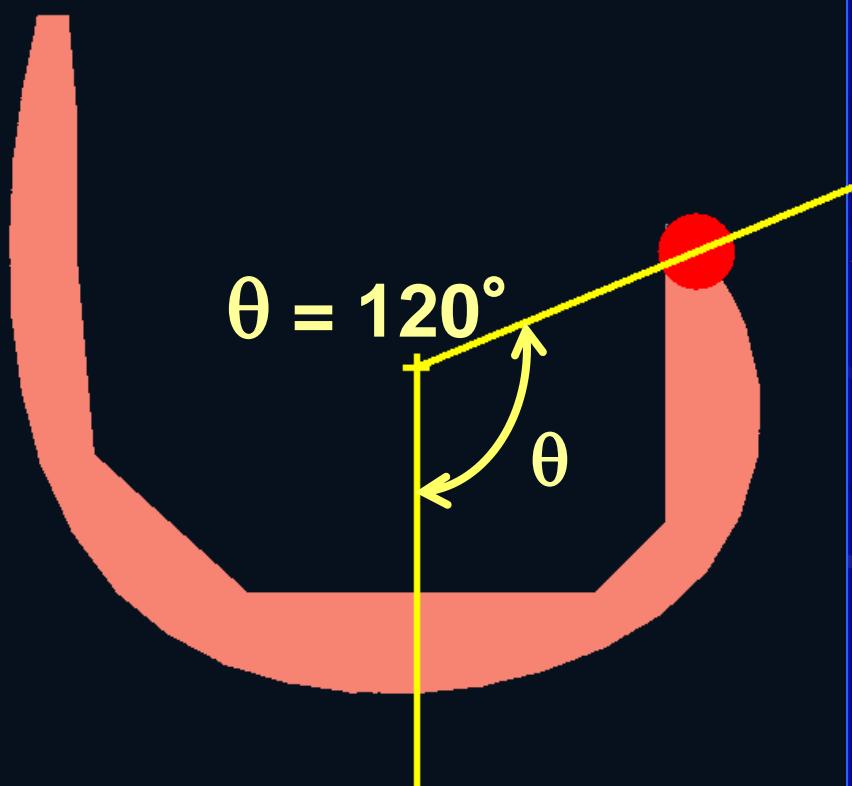
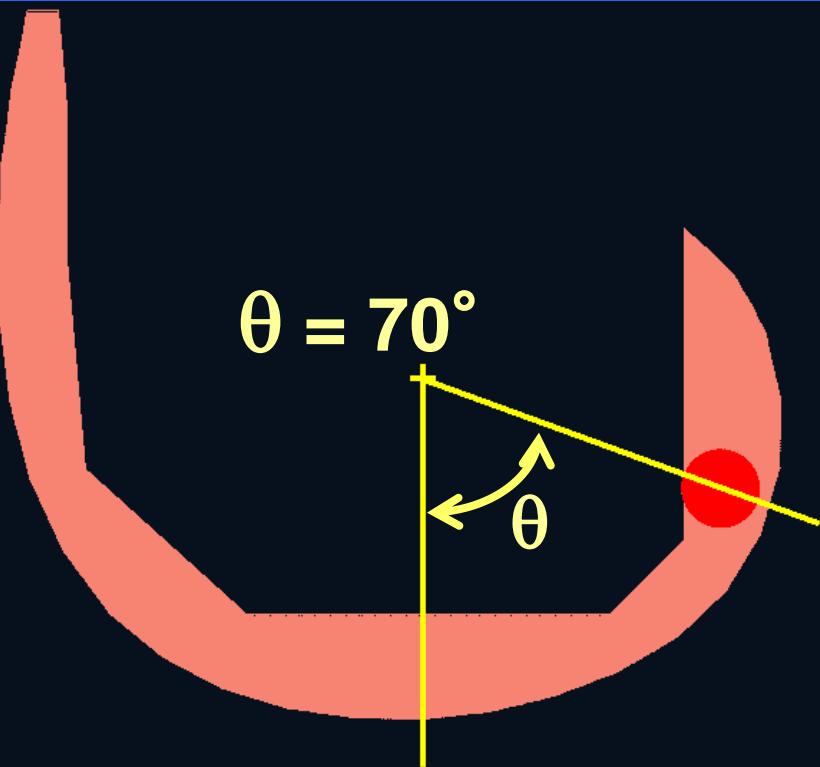


Suivant la valeur de θ :

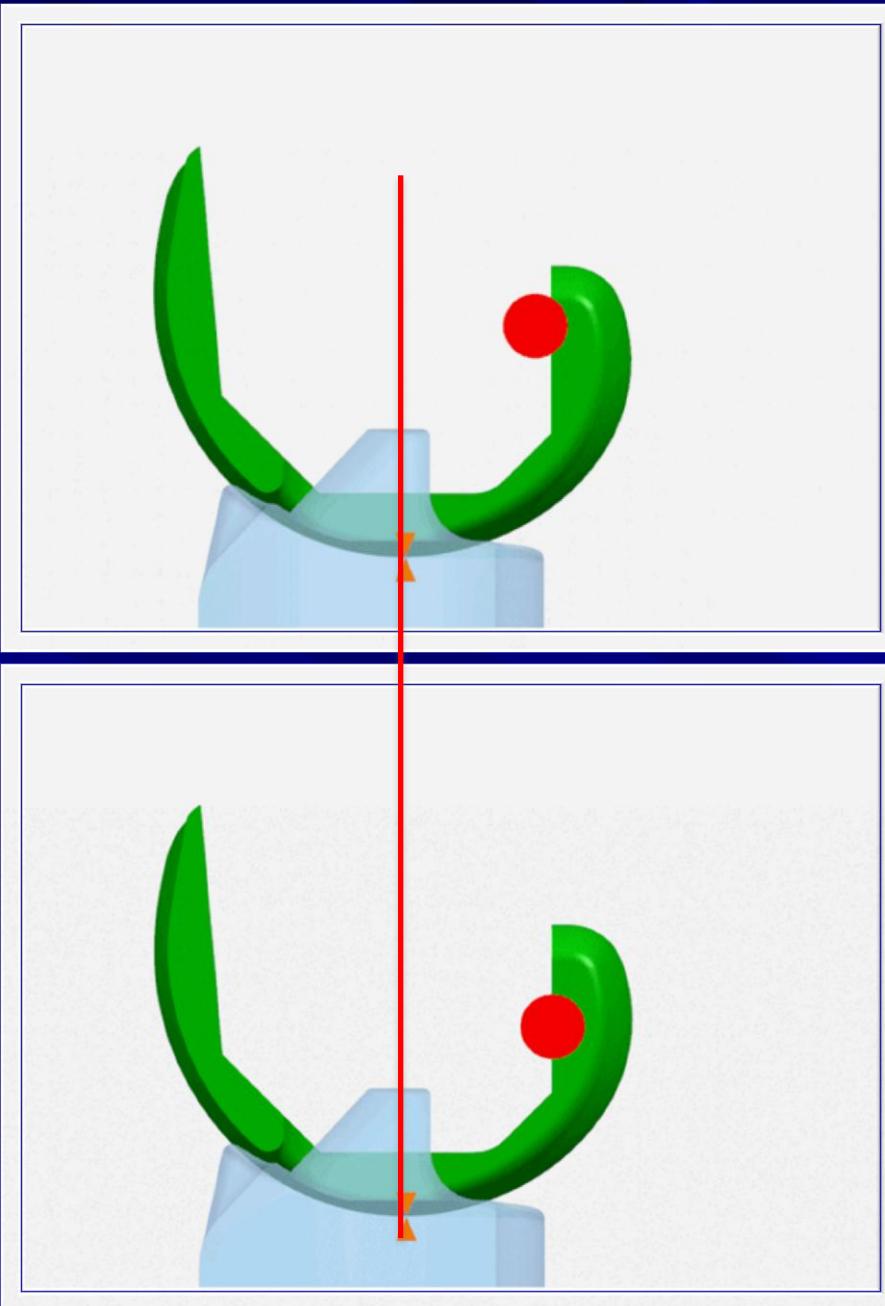
- ➡ Action rapide ou tardive suivant l 'angle de flexion

Exemples :

Prothèse	Fabricant	Angle d'entrée en fonction
Profix	Smith & Nephew	45°
Natural Knee	Zimmer	67°
AGC	Biomet	20°
ATTUNE	Depuy	90°
ANATOMIC	Amplitude	90°
Optetrach	Exactech	65°



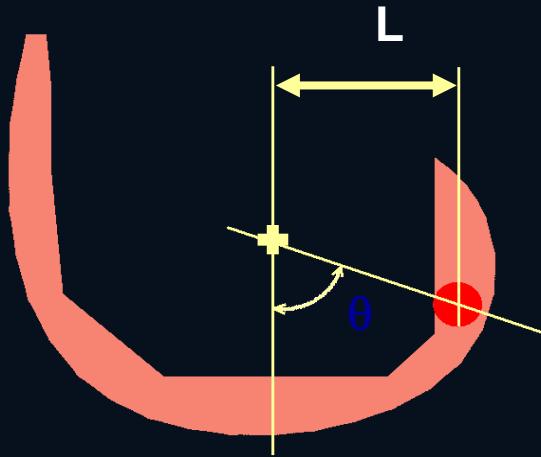
SIMULATIONS



Un paramètre essentiel

L'angulation d'engagement du plot-came





Suivant la valeur de L :

$L \approx 0$

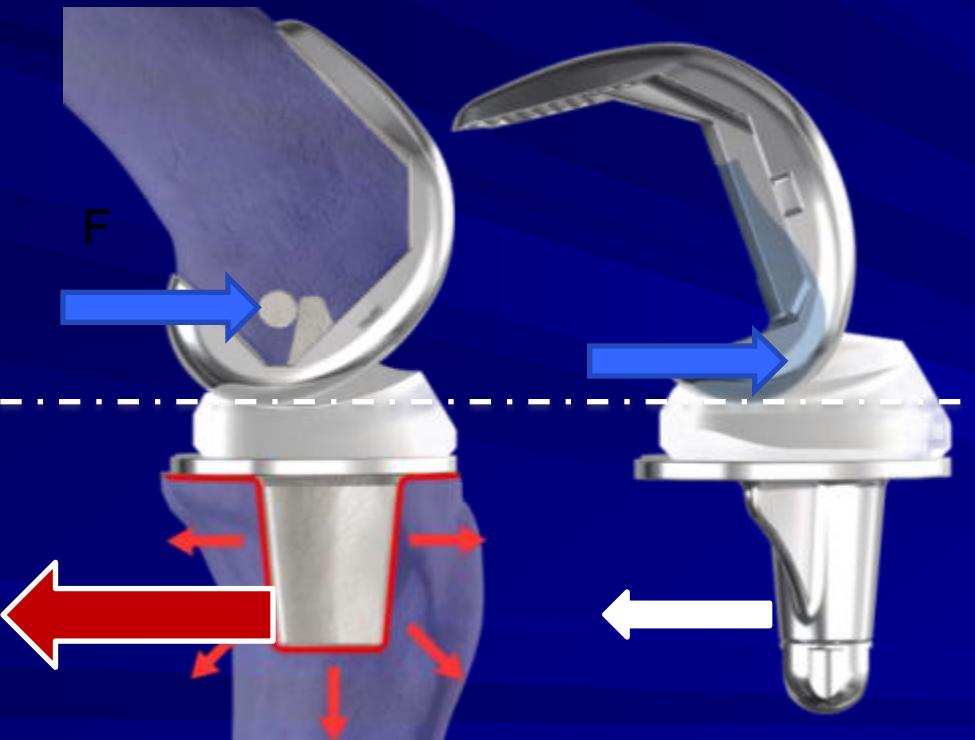
- ⇒ Peu de Roll Back
- ⇒ Nécessité d'un plot haut avec risque de rupture

$L \approx R_f$ postérieur

- ⇒ Augmentation du Roll Back
- ⇒ Plot + court et + résistant

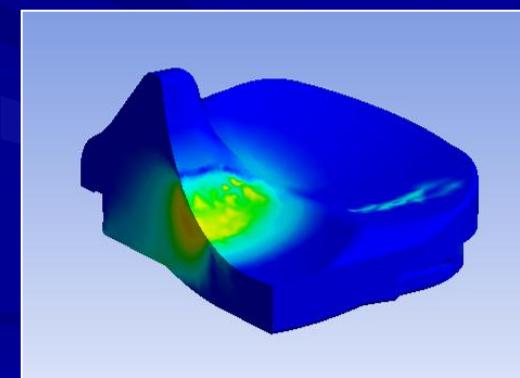
BENEFICES THEORIQUES

abaissement du point de contact



Le point de contact du système de PS est plus bas que sur les systèmes plot-came classiques

- Diminution du risque de rupture du plot
- Diminution des contraintes sur la quille tibiale (diminution du bras de levier)



2. Stabilité

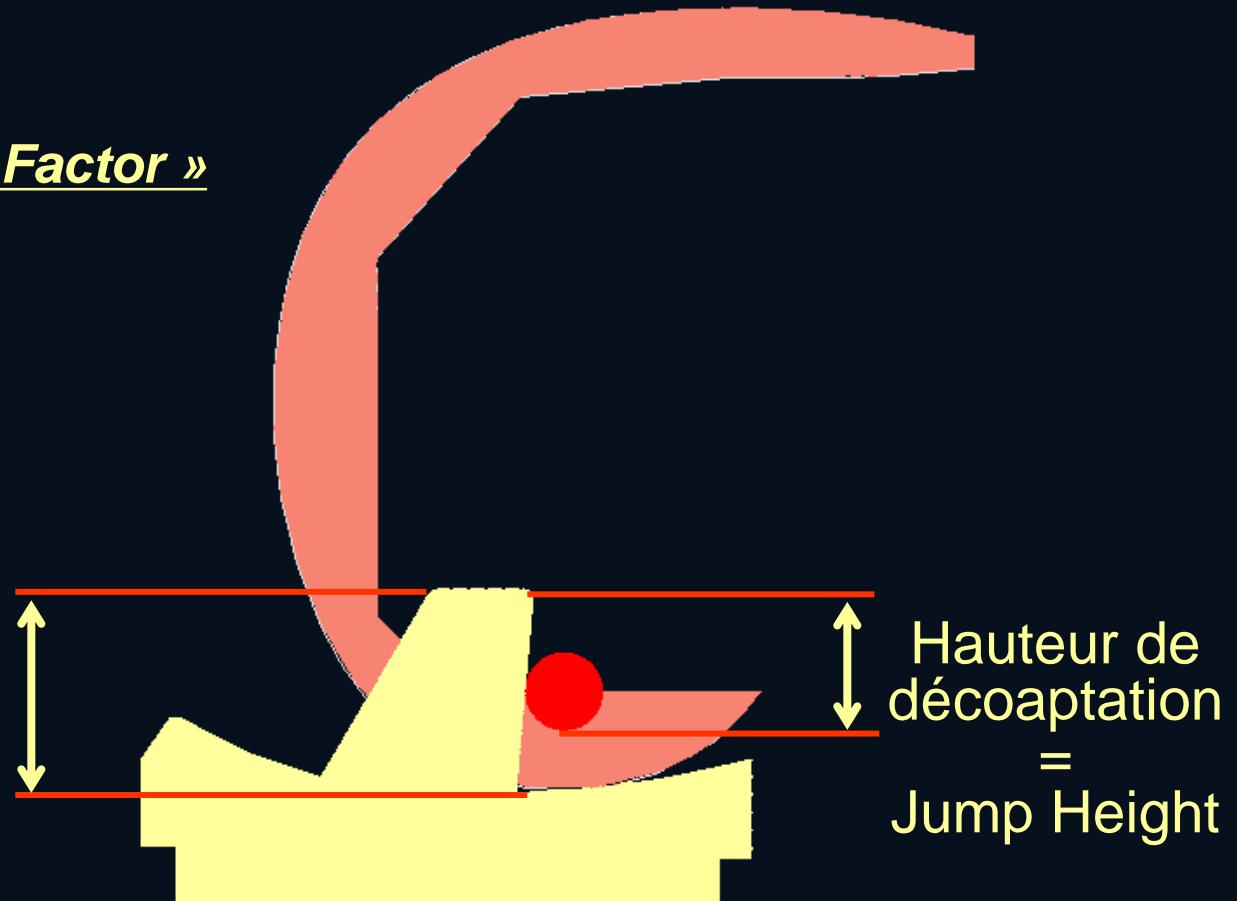
Définition de la décoaptation

« Jump Height »

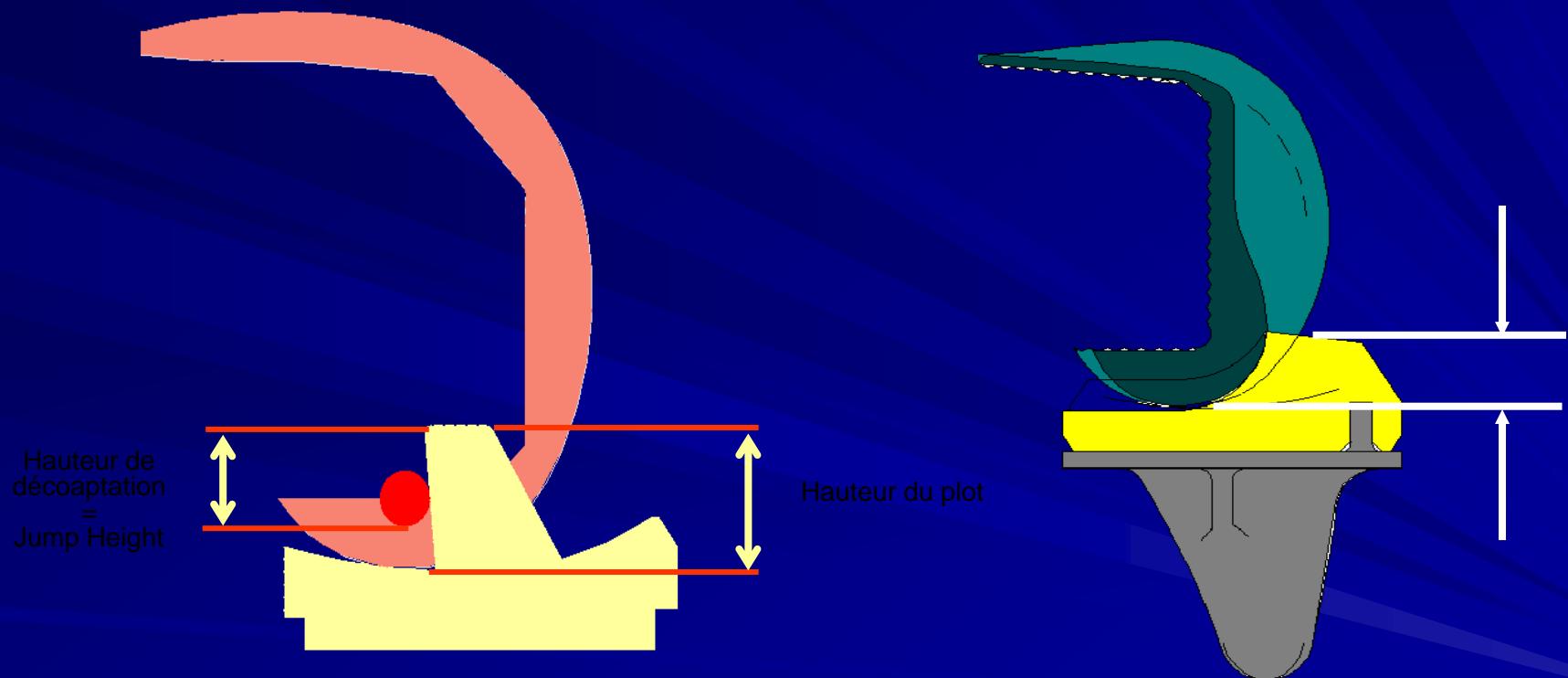
ou

« Dislocation Safety Factor »

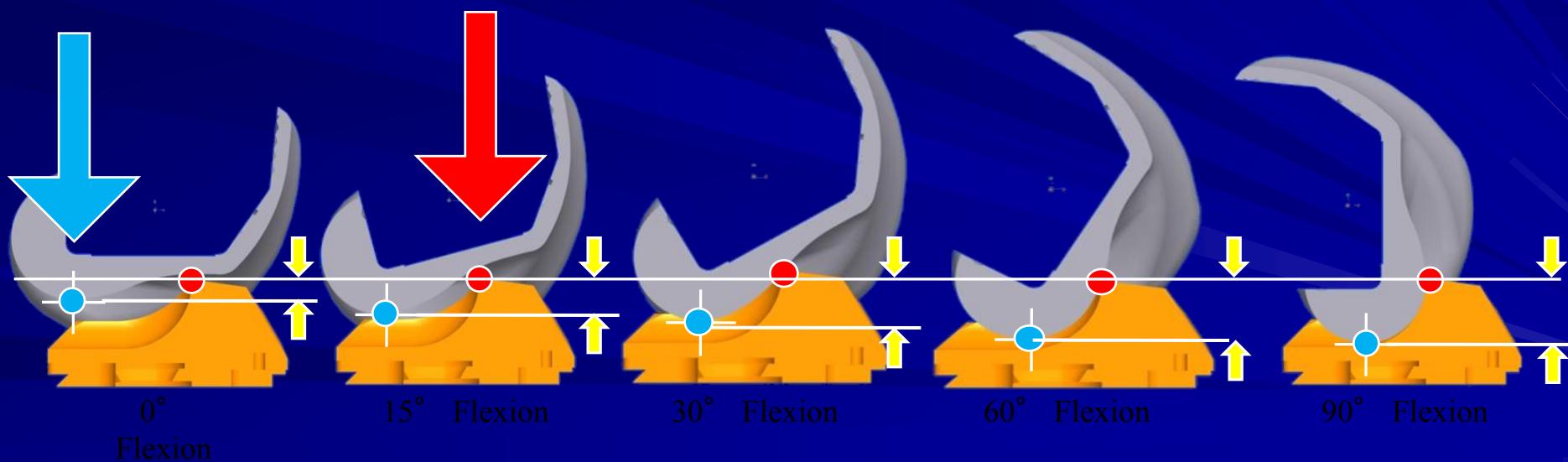
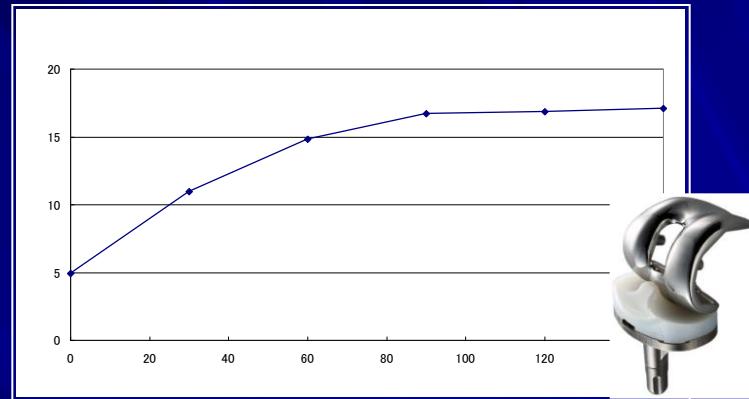
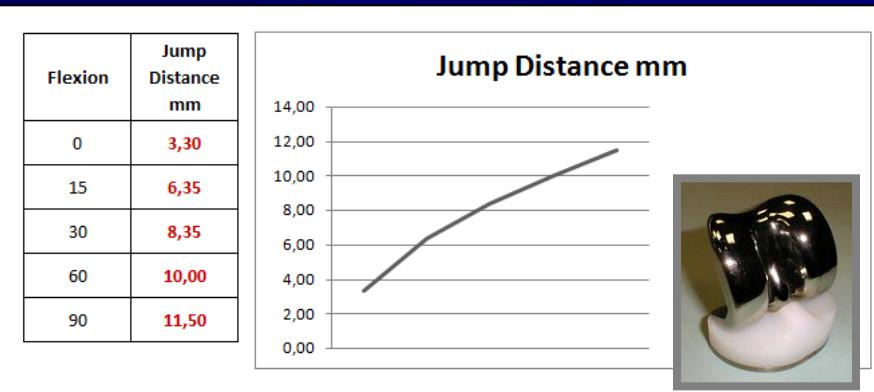
Hauteur du plot



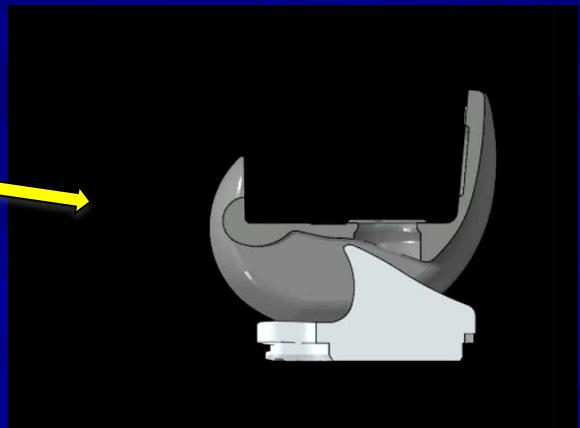
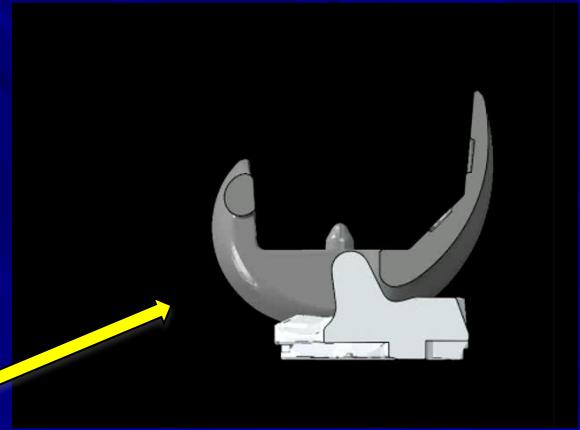
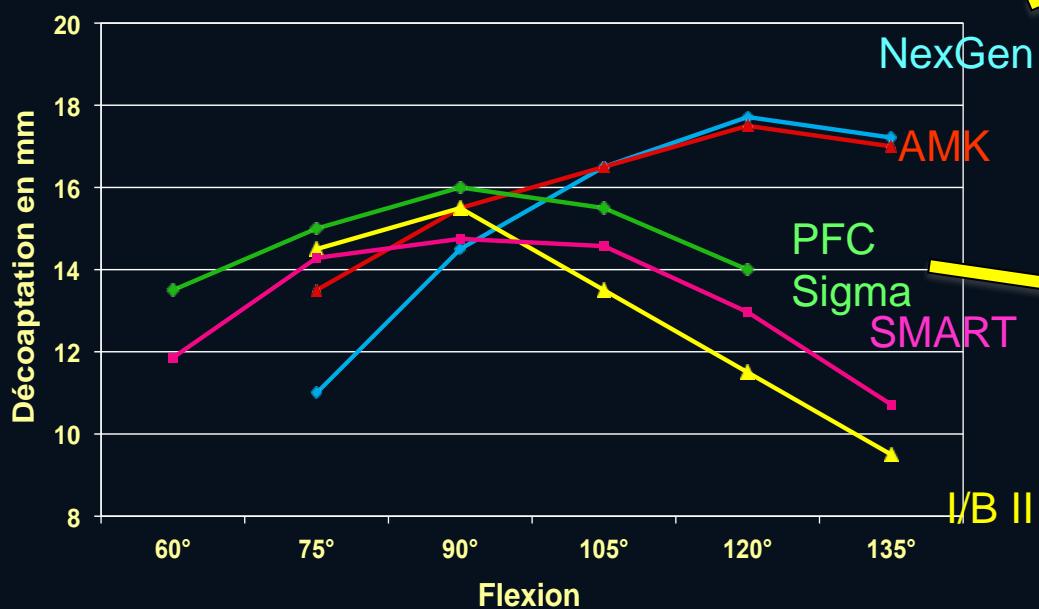
Conditionne la stabilité



VARIE AVEC LA FLEXION

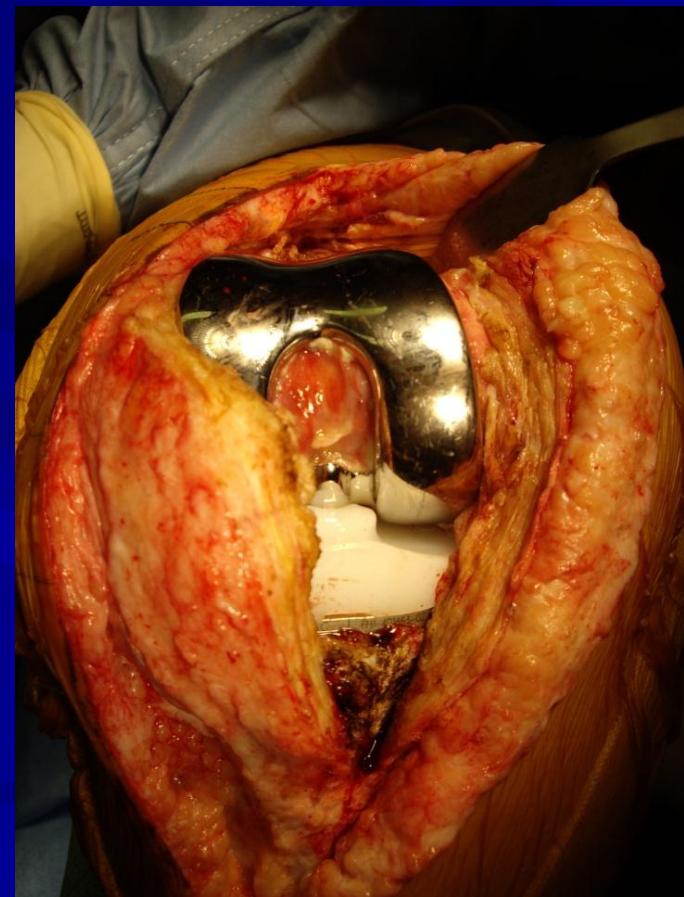
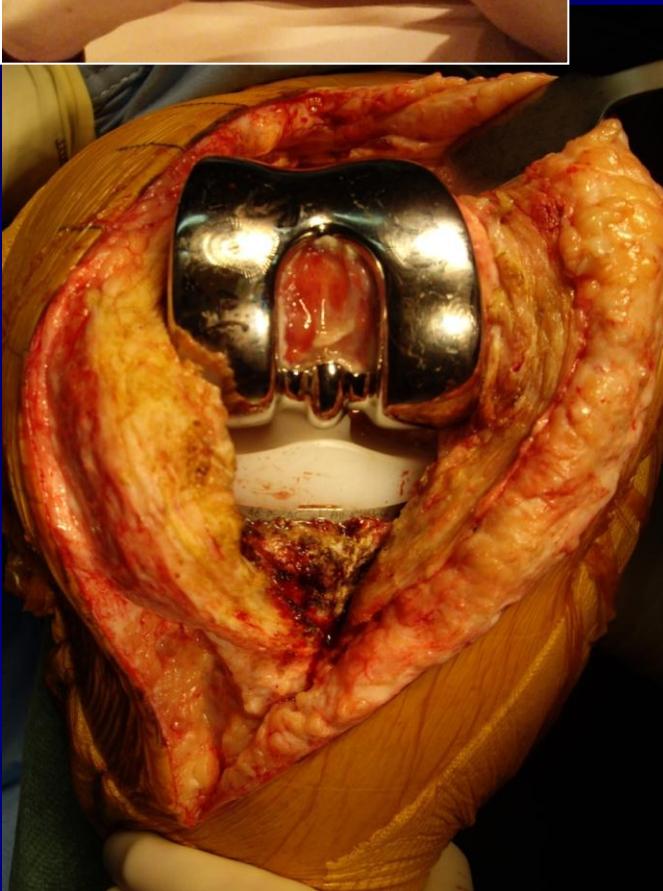


Comparaison des hauteurs de décoaptation



En pratique



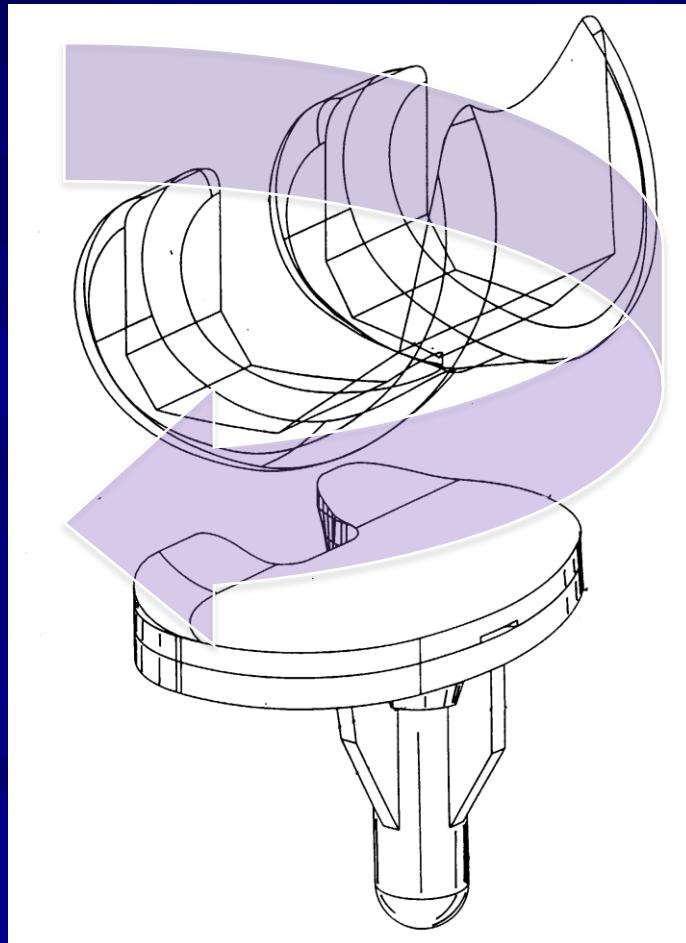


3. Contrainte

Les contraintes dans le plan horizontal

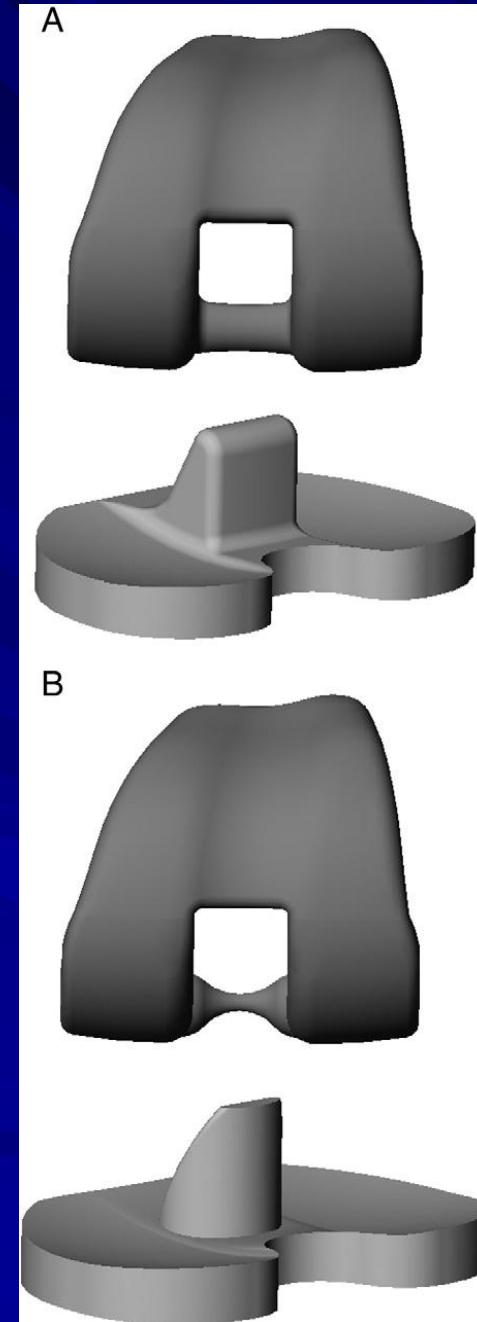
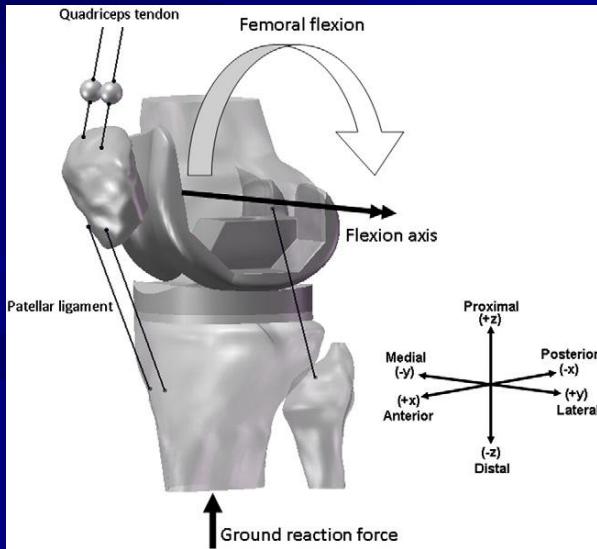
contraindre

Libérer

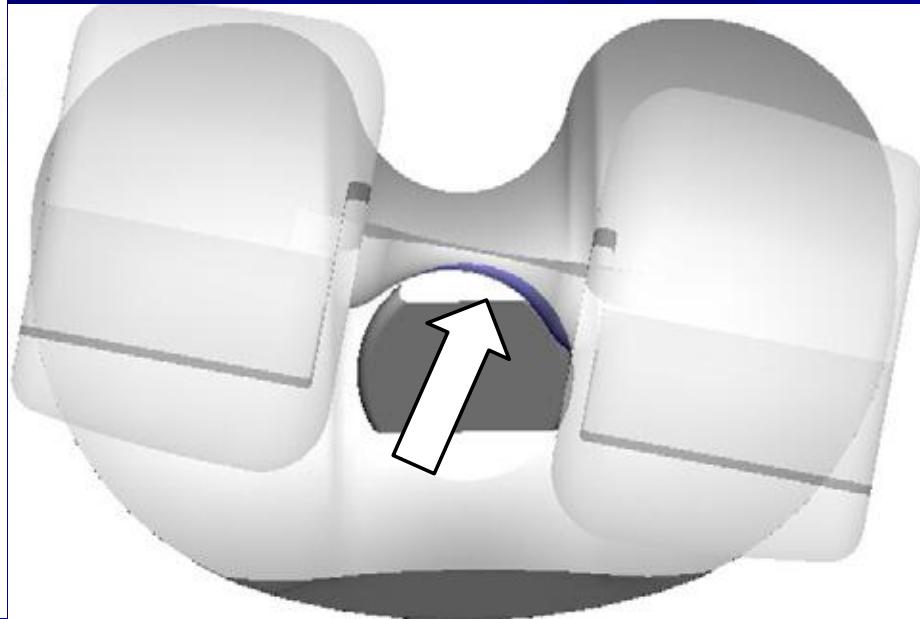
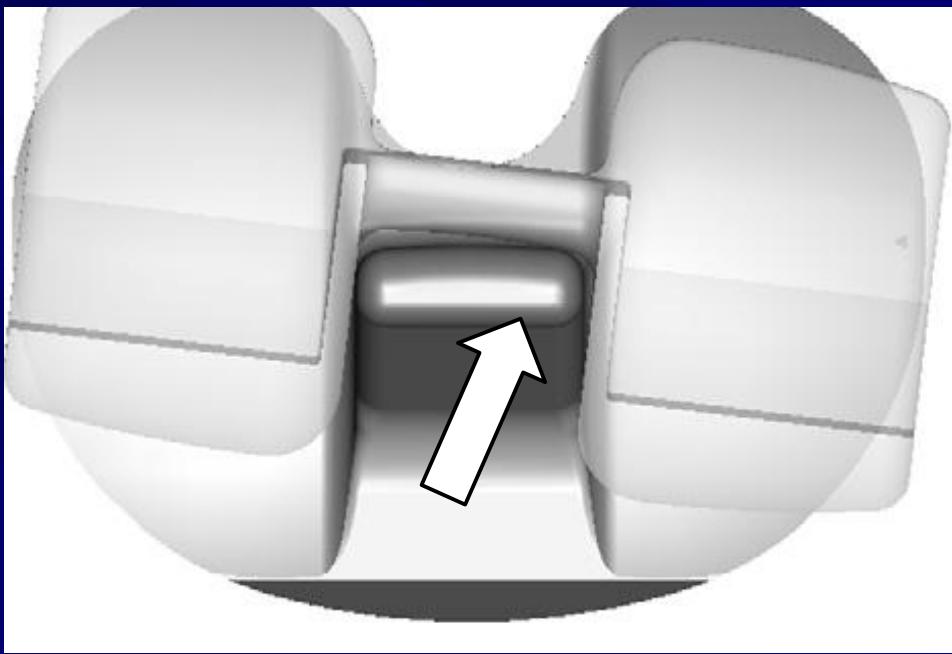


Influence of post-cam design of posterior stabilized knee prosthesis on tibiofemoral motion during high knee flexion

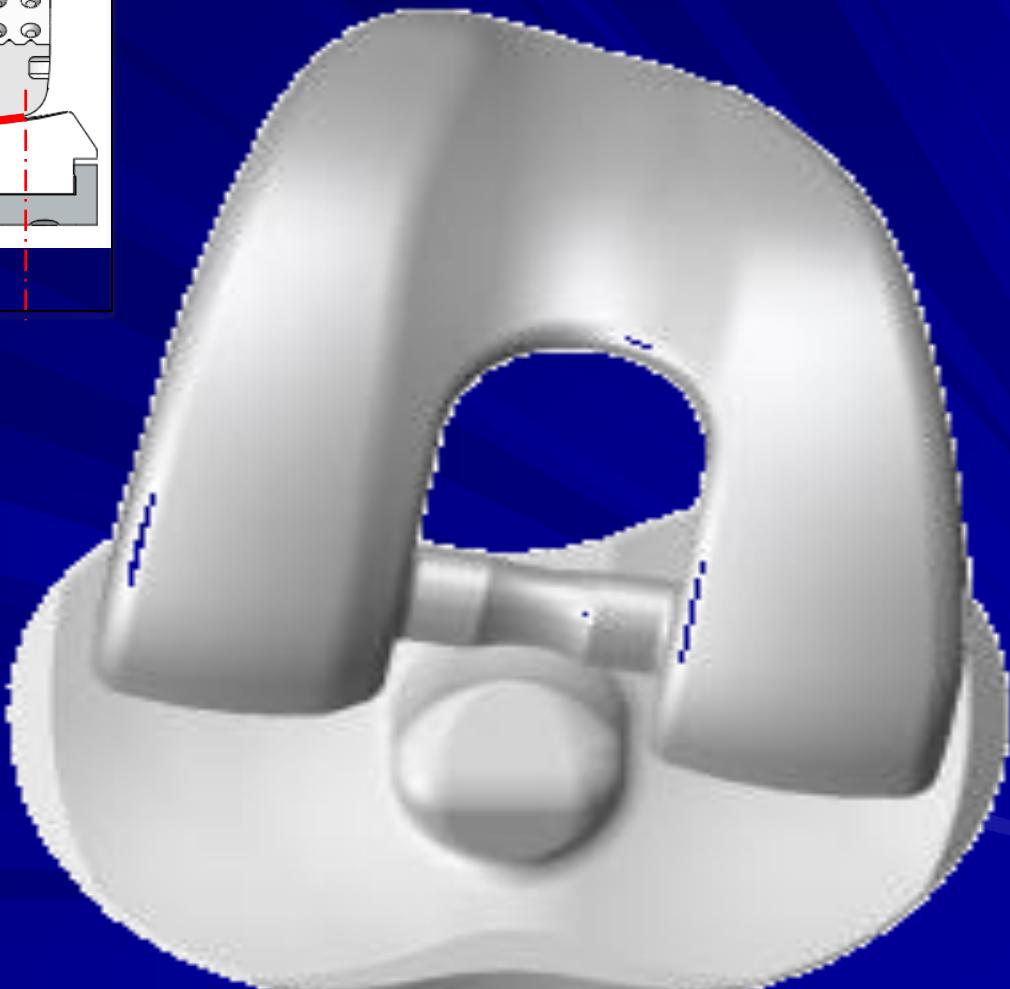
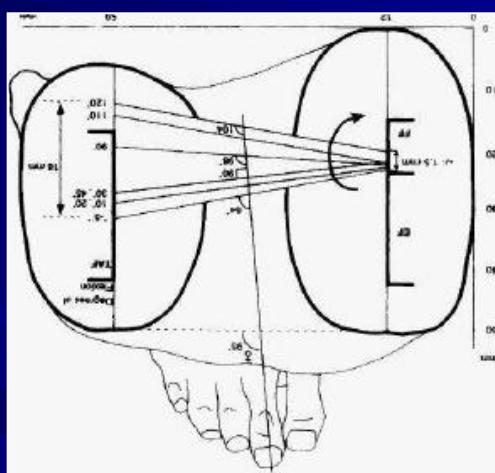
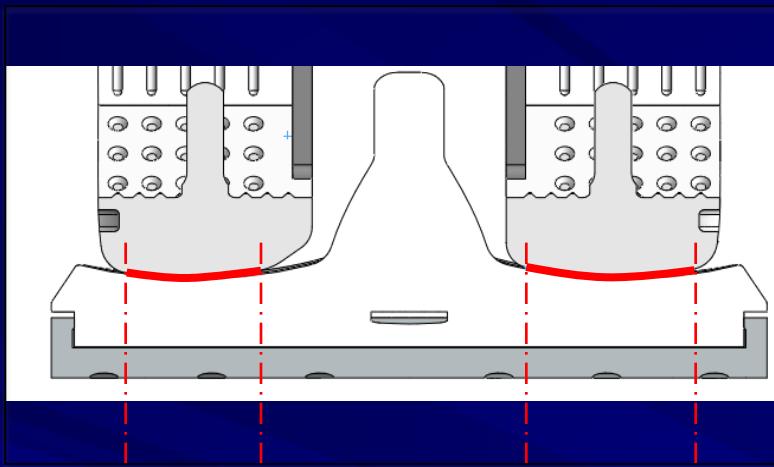
Kun-Jhih Lin , Clin Biomech 2011 Oct



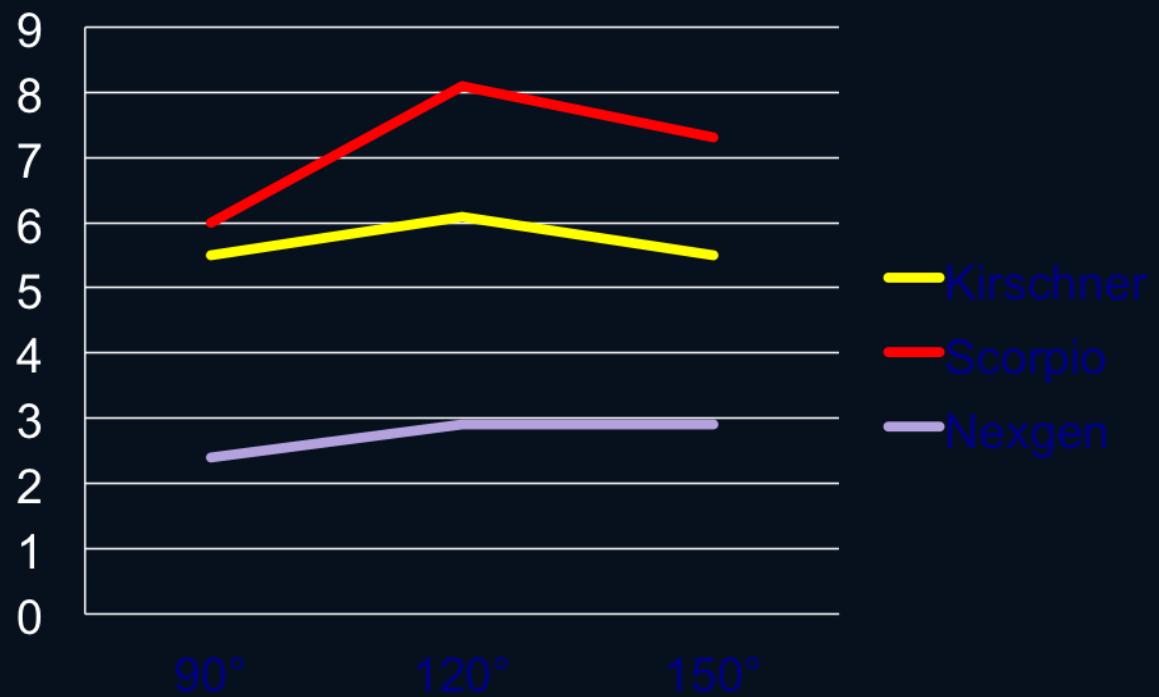
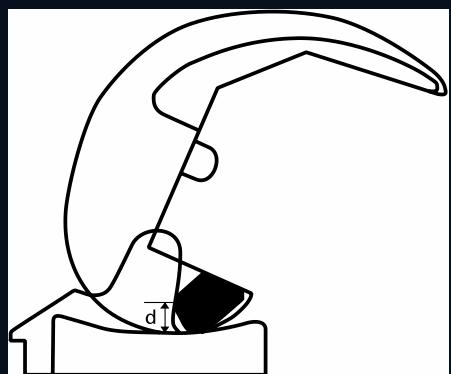
Limitation du conflit



Asymétrie de rayon des condyles



Hauteur d'application



Des contraintes: analyse in vitro

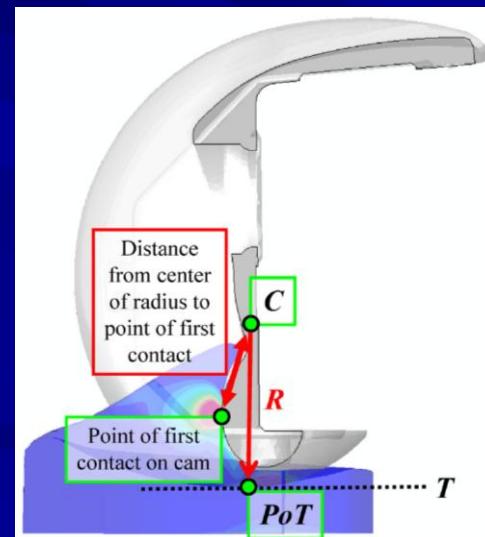
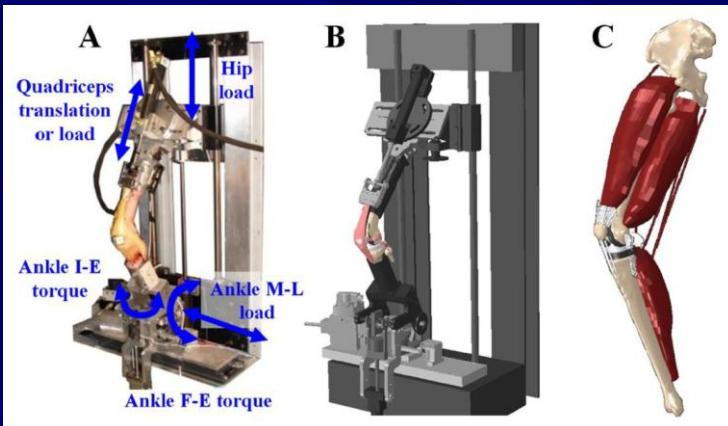
Mechanics of Post-Cam Engagement during Simulated Dynamic Activity

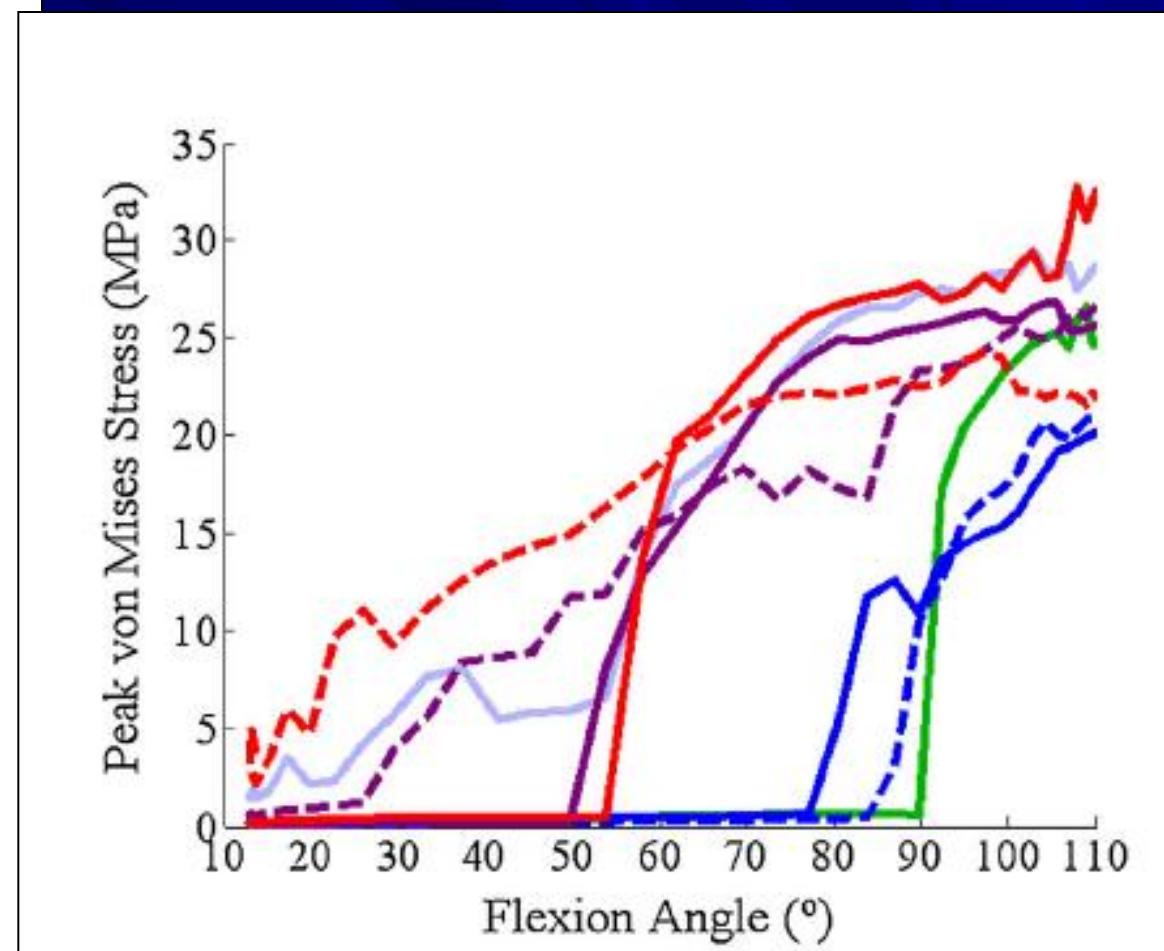
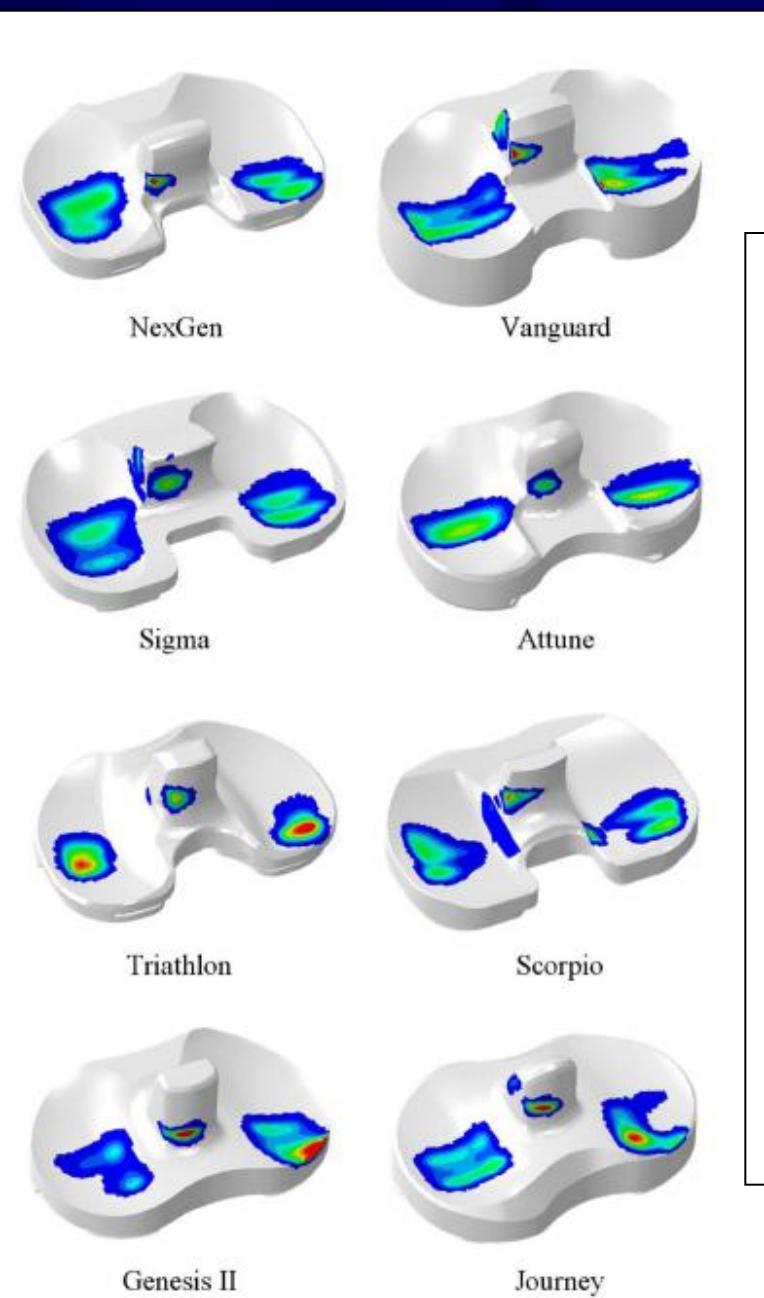
Clare K. Fitzpatrick,¹ Chadd W. Clary,^{1,2,3} Adam J. Cyr,² Lorin P. Maletsky,² Paul J. Rullkoetter¹

¹Center for Orthopaedic Biomechanics, University of Denver, 2390 S. York St., Denver, Colorado 80208, ²Experimental Joint Biomechanics Laboratory, University of Kansas, Lawrence, Kansas, ³DePuy Orthopaedics, Warsaw, Indiana

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Des contraintes: analyse in vivo

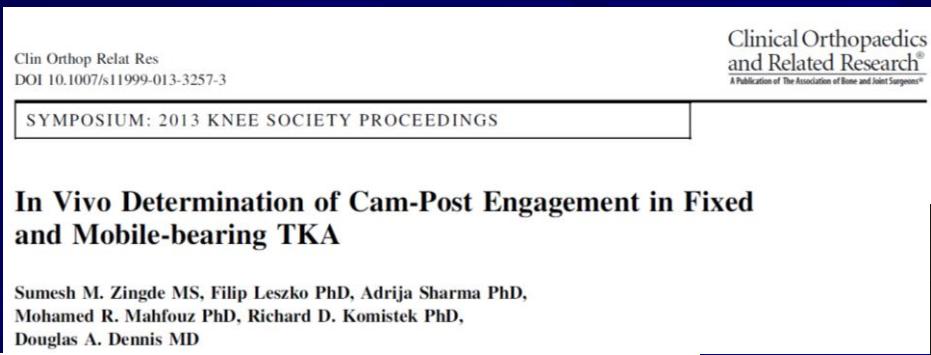
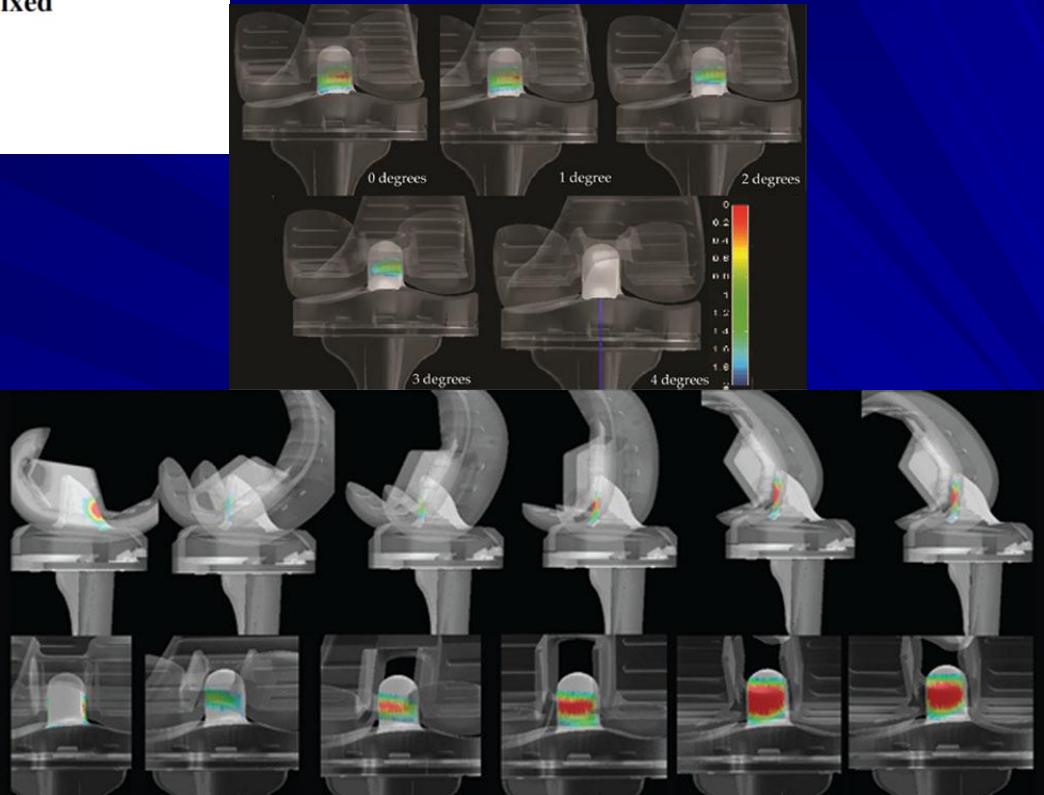


Table 1. Demographic information for all subjects in the three groups

Group	Number of subjects	Number of TKAs	Age (years)
RP-PS group	8	9	68.0 (SD = 6.9)
FB-PS group	5	5	69.2 (SD = 10.5)
BCS group	9	10	67.1 (SD = 8.9)

RP-PS = rotating-platform posterior-stabilized; FB-PS = fixed-bearing posterior-stabilized; BCS = bicruciate-stabilized.



Stress sur la came dépend
Des rotations
Des contraintes antéro-postérieures
De la forme: substitution bi-croisée ou
PS seule

Analyse d'explants

23 explants

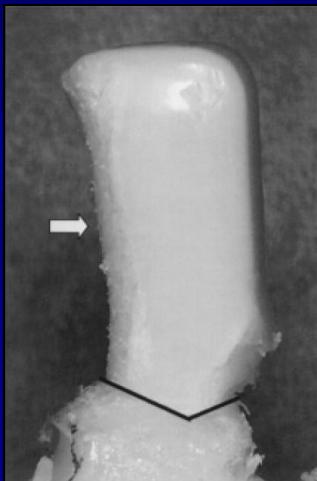
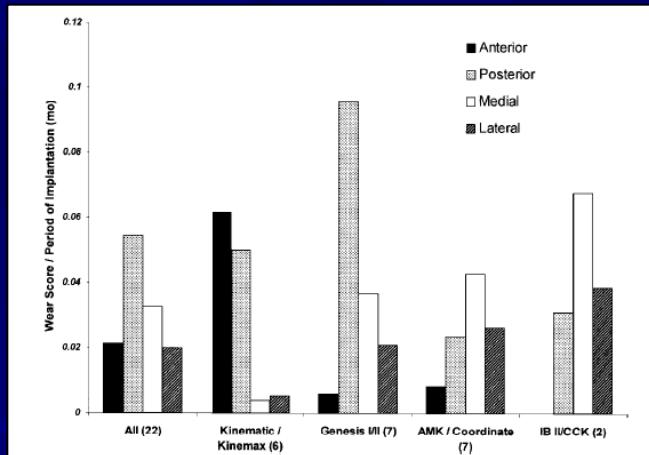
Moyenne de 35.6 mois (de 2.3 to 107.2 mois)

4 compagnies

39.9% avaient des déformations de la cam

7 explants (30%) présentaient des déformations majeures de la cam

2 des fractures



TIBIAL POST WEAR IN POSTERIOR STABILIZED TOTAL KNEE ARTHROPLASTY

AN UNRECOGNIZED SOURCE OF POLYETHYLENE DEBRIS

BY S.K.T. PULOSKI, MD, R.W. MCCALDEN, MD, FRCSC, S.J. MACDONALD, MD, FRCSC,
C.H. RORABECK, MD, FRCSC, AND R.B. BOURNE, MD, FRCSC

*Investigation performed at The University of Western Ontario, London Health Sciences Centre-University Campus,
London, Ontario, Canada*

In conclusion, posterior stabilized implants may contribute to the production of additional wear debris and hence may influence the prevalence of negative outcomes such as osteolysis, aseptic loosening, and reactive synovitis. The surgeon should be aware that the cam-post interface is not a completely innocuous articulation, and manufacturers should be motivated to produce implants that maintain the function of the post while limiting wear or damage. Further analysis of the

SYMPOSIUM: PAPERS PRESENTED AT THE ANNUAL MEETINGS OF THE KNEE SOCIETY

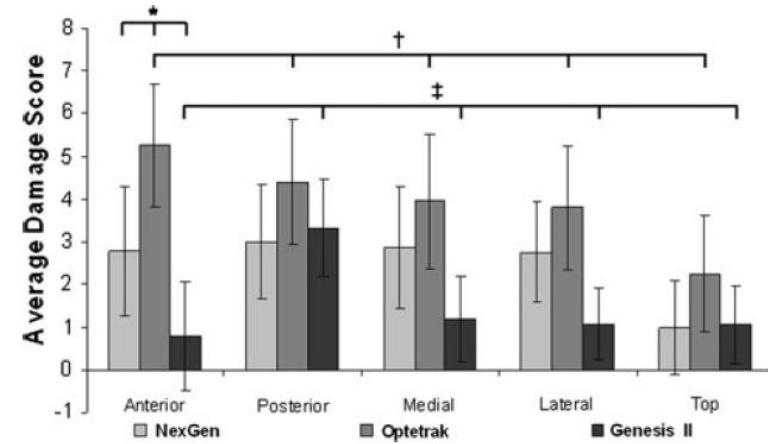
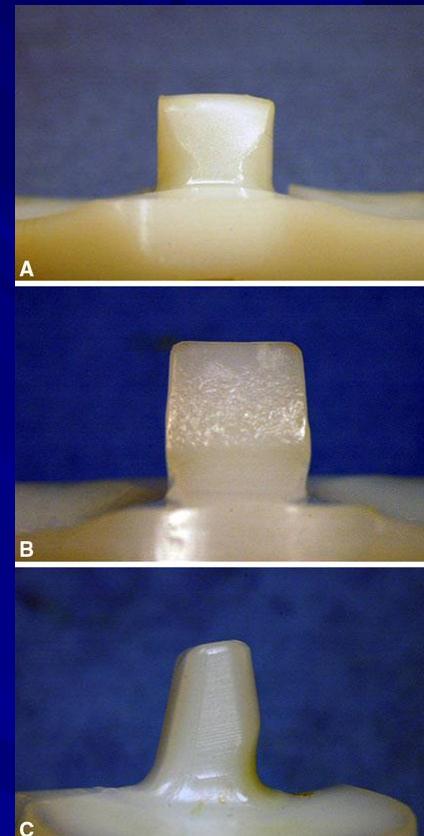
Implant Design Influences Tibial Post Wear Damage in Posterior-stabilized Knees

Mark M. Dolan MD, Natalie H. Kelly BS,
Joseph T. Nguyen MPH, Timothy M. Wright PhD,
Steven B. Haas MD

Table 1. Patient demographics

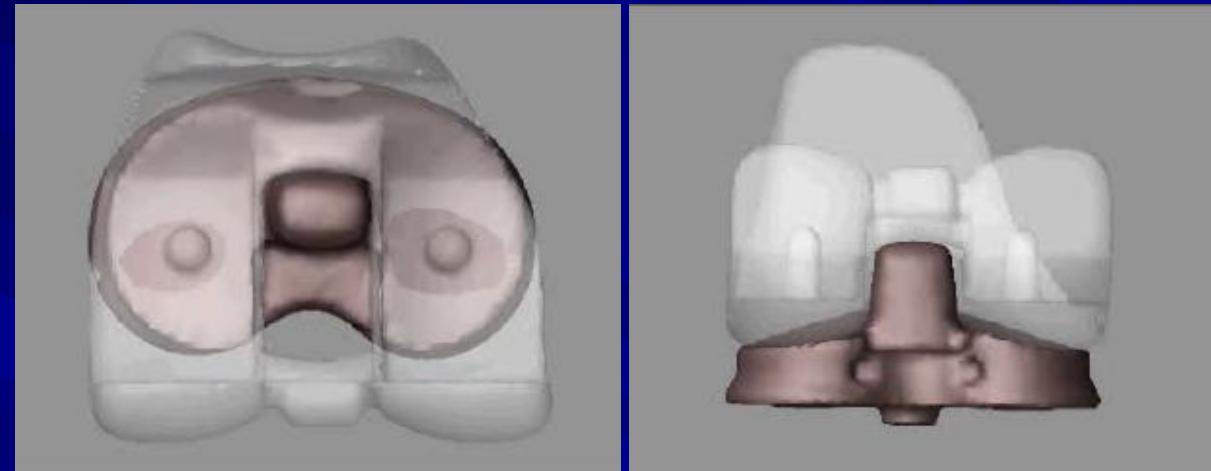
Variable	Genesis® II	NexGen®	Optetrak®	p value
Total number of patients	58	113	103	
Number of females	28 (49.1%)	66 (58.4%)	67 (65.0%)	0.144
Age (years)*	65.7 (\pm 12.2)	65.2 (\pm 10.4)	64.4 (\pm 11.8)	0.778
Length of implantation (years)*	1.44 (\pm 1.48)	2.14 (\pm 2.05)	2.60 (\pm 2.58)	0.006
	Range 0.02–8.01	Range 0.04–11.00	Range 0.03–10.13	
Side (number of patients)				
Left	28 (48.3%)	49 (43.4%)	53 (51.5%)	0.488
Right	30 (51.7%)	64 (56.6%)	50 (48.5%)	
Body mass index*	30.9 (\pm 7.0)	30.1 (\pm 6.7)	32.0 (\pm 6.4)	0.111
Reason for revision (number of patients)				
Infection	19 (34%)	39 (35%)	34 (35%)	0.331
Loosening	7 (12%)	21 (19%)	15 (15%)	
Instability	11 (20%)	28 (25%)	22 (23%)	
Stiffness	11 (20%)	19 (17%)	14 (14%)	
Miscellaneous	8 (14%)	4 (4%)	13 (13%)	

* Values are expressed as mean (\pm SD).



Et le plan frontal ?

- Pas de contrainte d'une PTG PS
« standard »





Increasing Constraint



Inconvénients potentiels d'augmenter la contrainte



- Transmission des contraintes (sagittale, frontales et horizontales +++) au niveau de l'interface os/ciment/prothèse,
- Stress à l'interface est proportionnel au degré de contrainte ($\rightarrow \uparrow$ usure ou descellement?)
- Limitation de la rotation

TAKE HOME MESSAGE

Les effets de la Came de postéro stabilisation dans le plan frontal et sagittal

1. Déplacement induit par :

-Position relative de la came et du plot, dessin de la came et du plot.

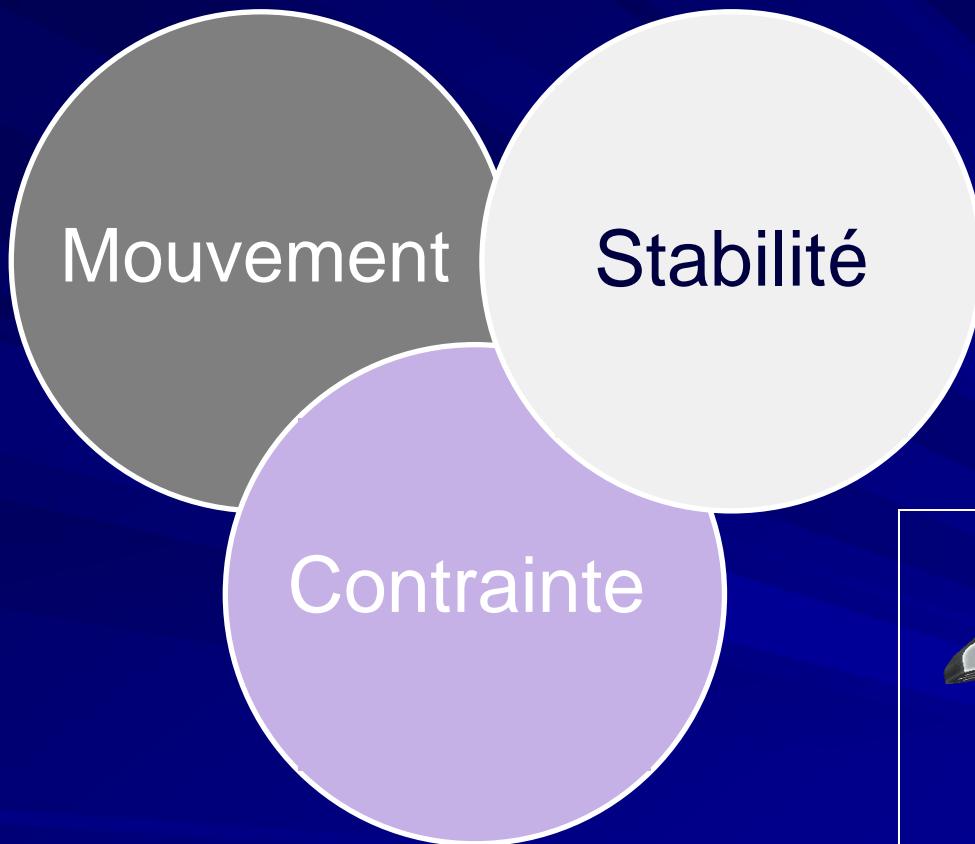
2. Stabilité induite par :

-Congruence, hauteur de décoaptation (dislocation safety factor), variable selon l'angle de flexion.

3. Contraintes induites par :

-Hauteur d'application, surface de contact, stress de contact maximum, effet de la rotation interne.

Une affaire de compromis...



Plateau fixe / Plateau mobile

Pourquoi ?



- “Premature polyethelyne wear is a major cause of failure of TKA”
- Etiologies
 - Technique
 - Usure minime du PE
 - Mauvais dessin d’implants (i.e. locking mechanism)
 - Sterilisation

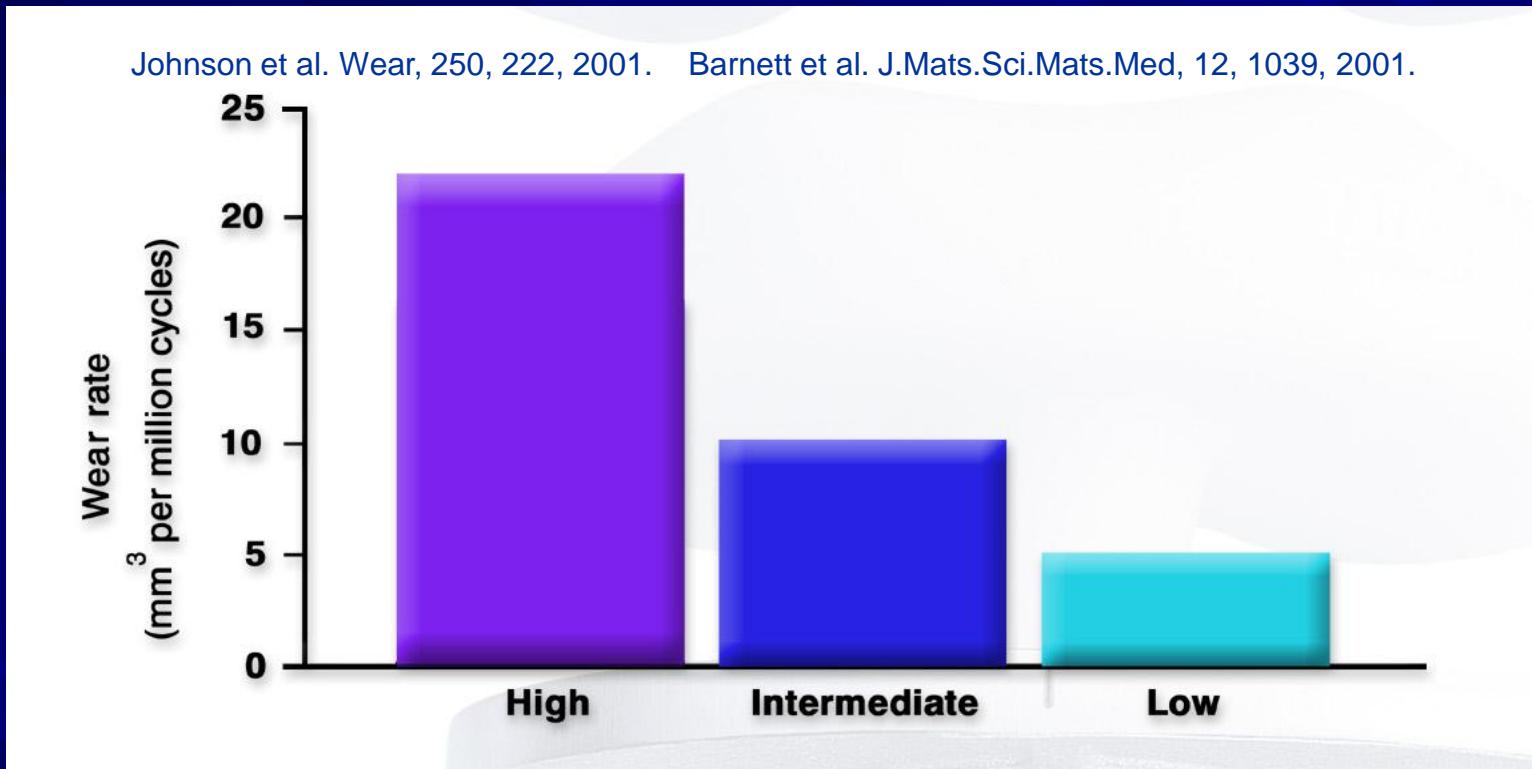
Pourquoi c'est important ?

- PTG sont implantées chez des patients de plus en plus jeunes et toniques.
- Durée de vie augmente.
- Attentes ++



Plateau fixe

“Wear highly dependent on displacement and rotation kinematics”



“Highly active patients may produce high wear with fixed bearing knees”

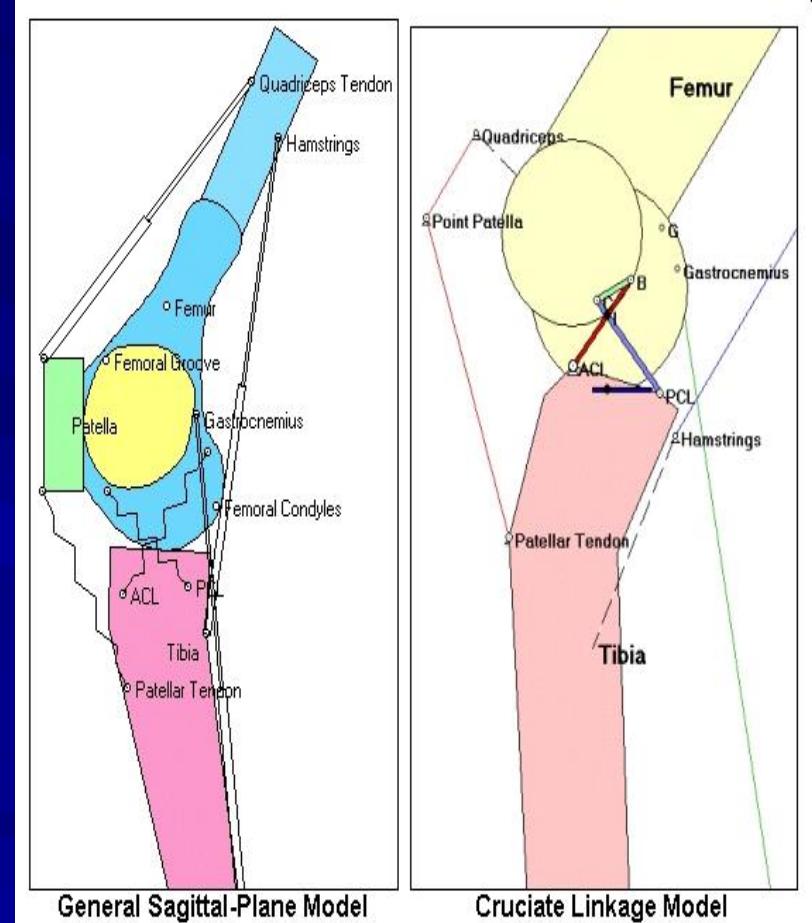
Comment augmenter la longévité des PTG



- Meilleur design
- Améliorer les matériaux
- Améliorer le stockage et le processing.
- TECHNIQUE CHIRURGICALE

Le genou N'EST PAS une charnière

“To date, no model can explain all the motions in the knee”



Anteroposterior Femorotibial Translation

- Fixed bearing **posterior cruciate retaining (PCR) TKA**
 - Contact postérieur en extension
 - Glissement fémoral antérieur en mid-flexion communément observé
 - Rarement de roll back fémoral postérieur
 - Grande variabilité de schéma de répartition des contacts

Anteroposterior Femorotibial Translation

- Fixed bearing posterior cruciate substituting (PS) TKA
 - Posterior femoral rollback routinely occurs
 - Less than in the normal knee
 - Consistent contact pathways

Rotation fémoro-tibiale axiale

- **Normal:** rotation interne tibial en flexion extrême (screw-home mechanism)
- Amplitude réduite (vs. normal knees) après PTG :
 - Genou normal :
rotation moyenne (0-90°) = 16.5°
 - PTG :
rotation moyenne (0-90°) < 10°

Rotation fémoro-tibiale axiale

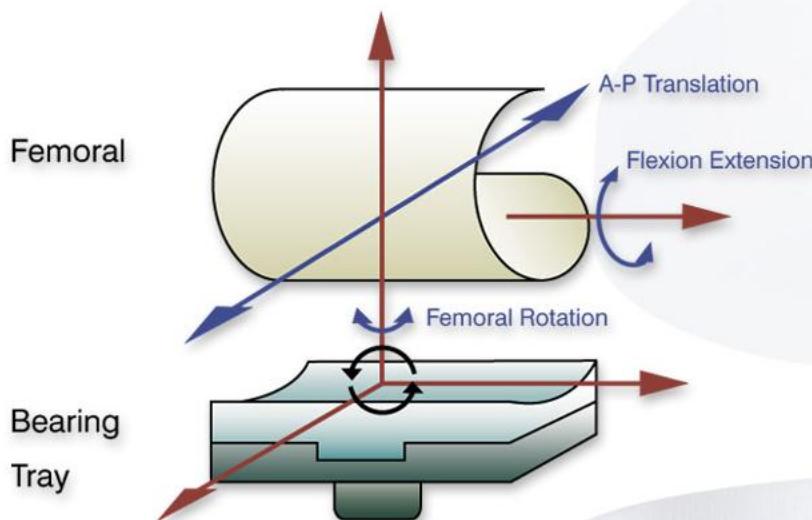
■ PTG à plateau mobile

- PE tourne avec le composant fémoral
- Rotation survient au niveau de la surface inférieure du PE (vs. surface supérieure avec les PTG plateau fixe)

Fixe vs Mobile

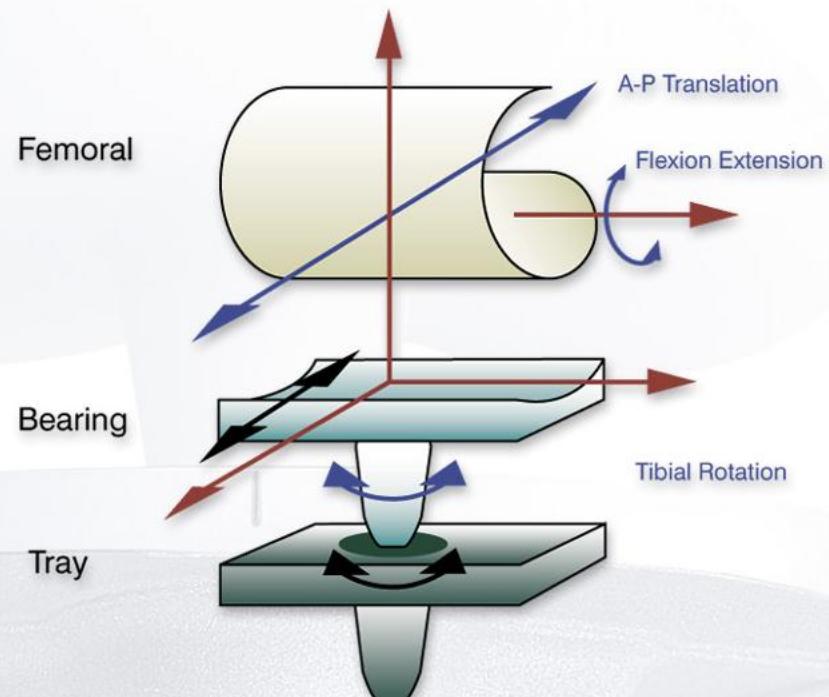
Fixed bearing

Multidirectional motion of femoral component relative to bearing

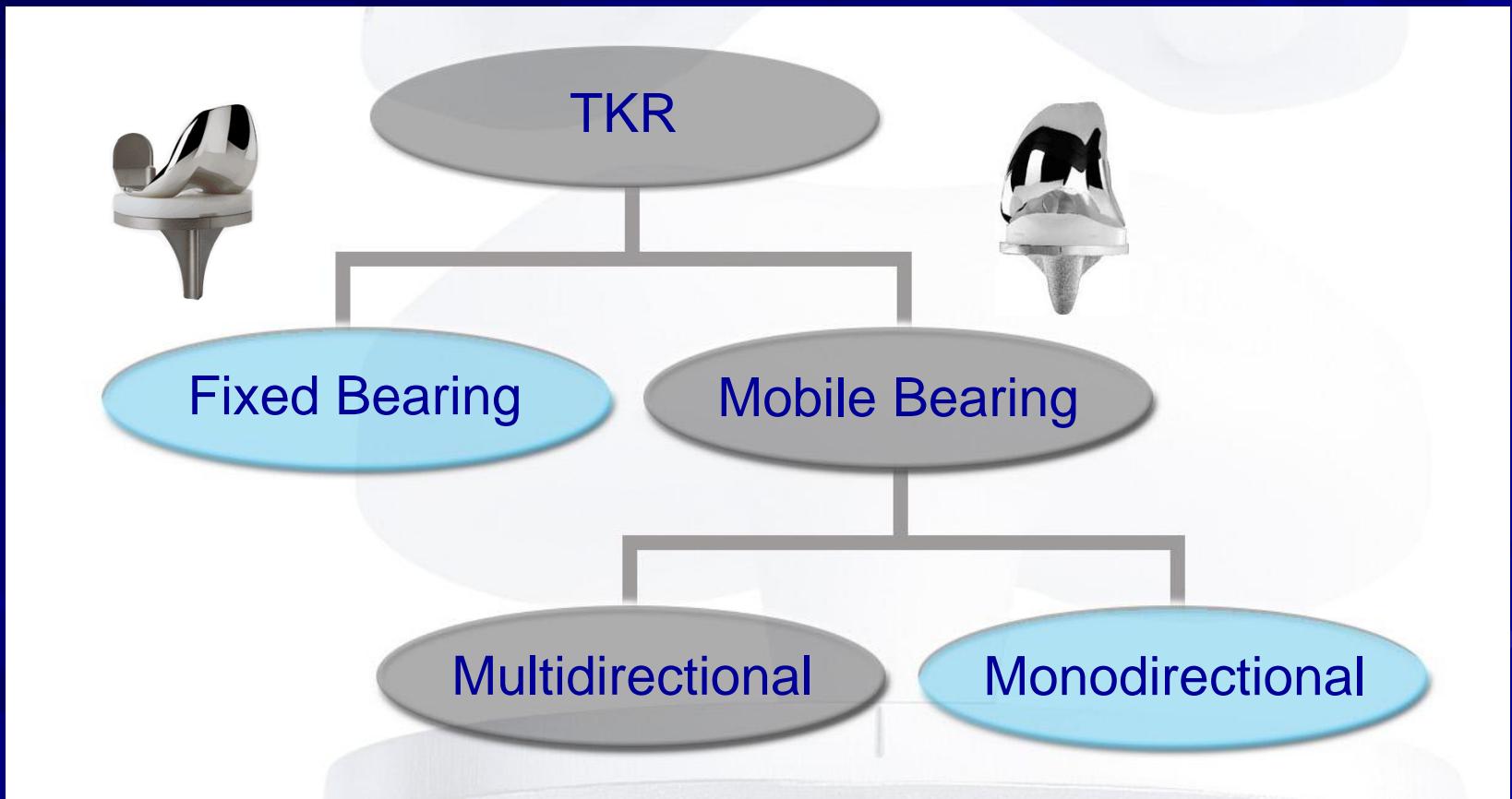


RP Mobile bearing

Bearing rotation decoupled:
Linear rotation at tibial counterface with reduced rotation at femoral counterface



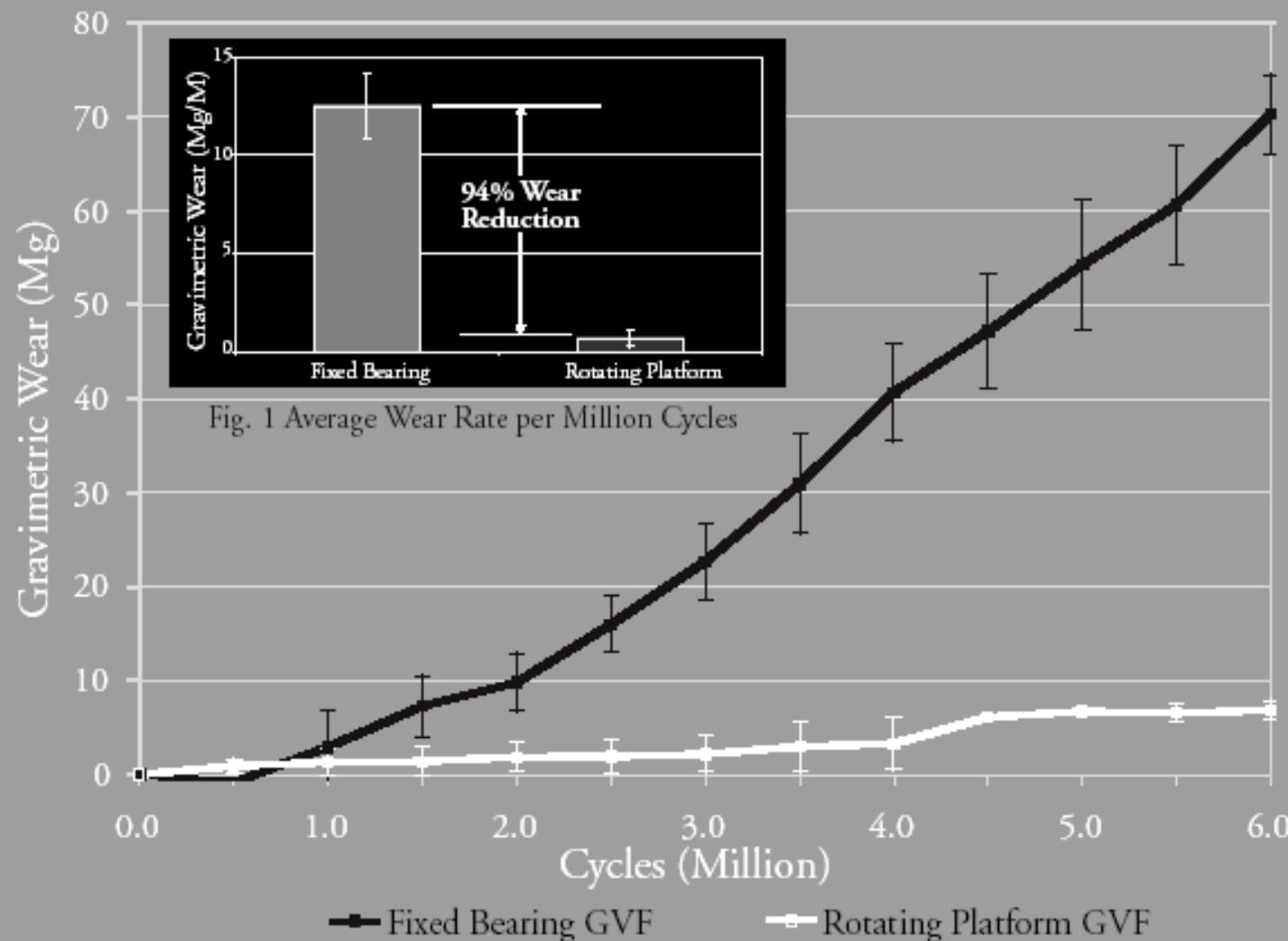
Design de PTG



Plateau mobile : 2 choix ...



Fixed Vs. Rotating Platform Wear



Y a-t-il tant de différence ?

Haider H and Garvin, CORR 2008

In vitro comparison fixed bearing versus rotating platform bearing design.

“Very low wear rates of both designs, but no significant difference between fixed bearing and RP”.

Etude d'explants

- Garcia RM, J
Arthroplasty 2009.
 - 40 retrievals of RP knees.
 - Short time to failure
 - Surface damage and undersurface wear in specimens.
 - RP not immune to wear.
- Ho, et al. CORR 2008
 - 15 retrieved RP specimens (mean time 115 months).
 - Low grade wear more likely in RP poly.
 - No asymmetric internal/external rotational wear noticed.

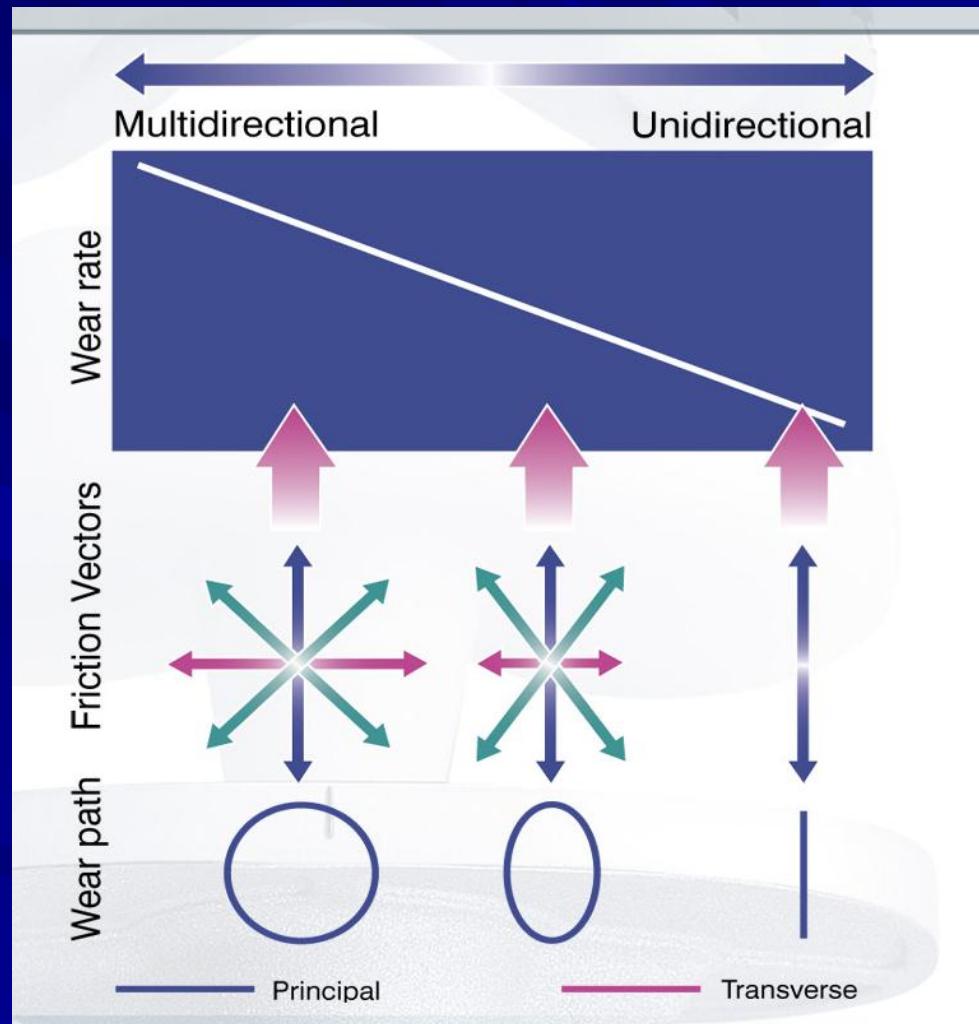
UHMWPE Kinematics

Multidirectional motion
accelerates UHMWPE wear

(Wang et al. 1996, Proc. IMechE, 210H, 141)

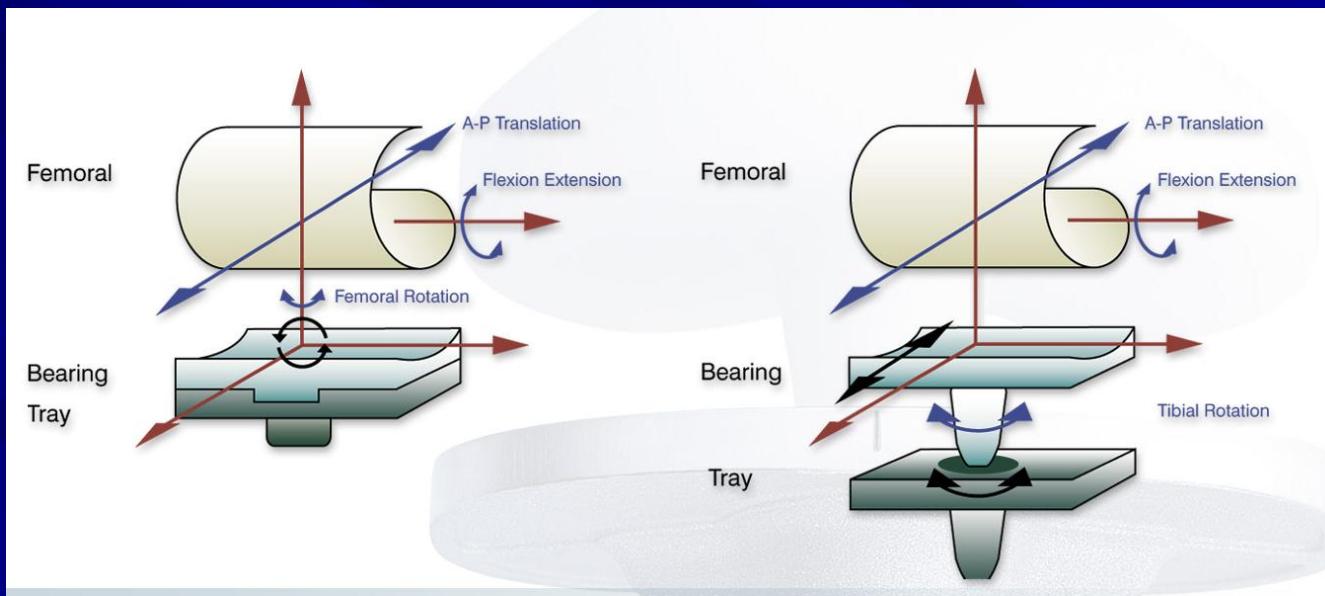
Monodirectional motion
reduces UHMWPE wear

(Marrs et al. 1999, J. Mats. Sci. Mats. Med. 10, 333)



En résumé...

*“Rotating platform mobile bearing TKR translates **multidirectional knee motion** into monodirectional rotation at the tray-insert interface with less multidirectional motion at the femoral-insert interface, thus reducing wear”*



Autres avantages théoriques

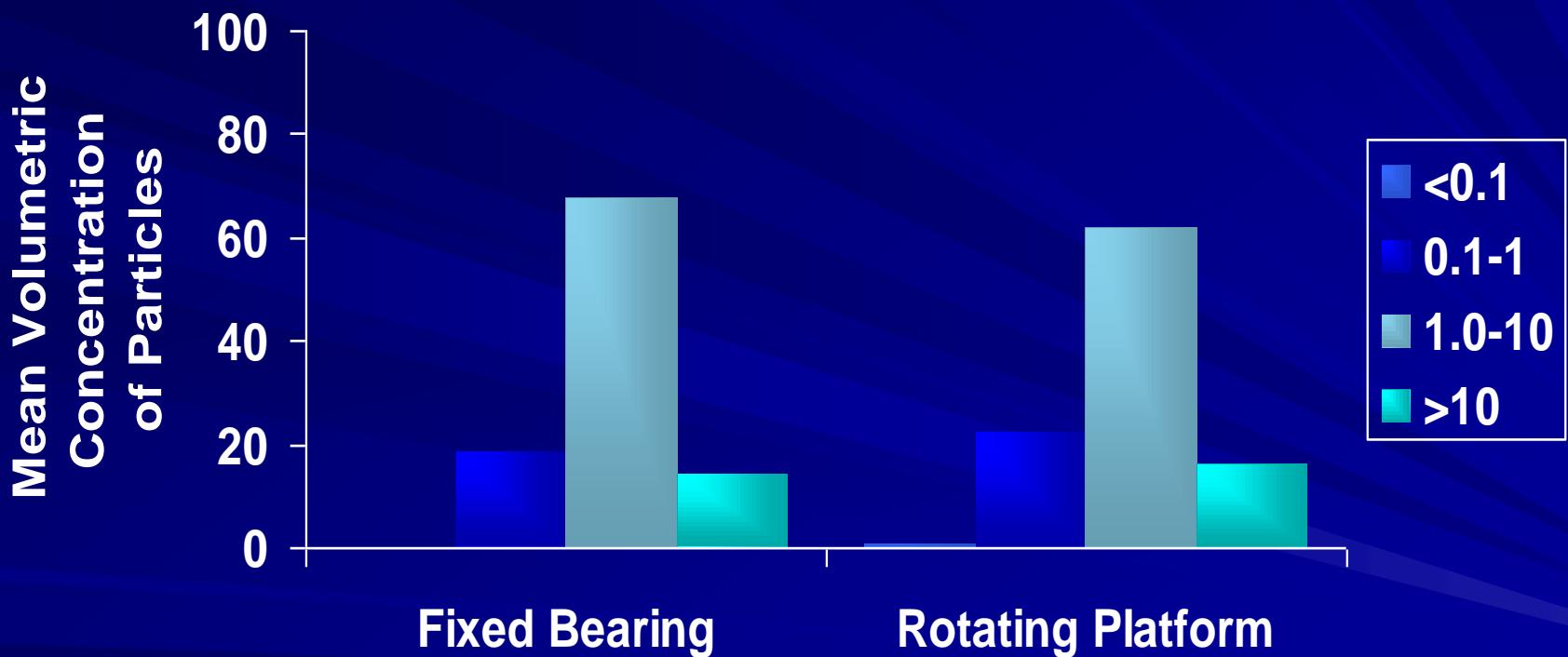
- Self alignment
 - Reduces edge loading.
 - Maintains pressures centrally
- Patellofemoral compartment
 - In vitro: improved (Rees, et al. CORR, 2005).
 - In vivo: No difference (Pagnano, et al. CORR 2004).



Avantages des plateaux mobiles

- Meilleure tolérance des erreurs de rotation tibiales ?
 - auto-correction
 - plus important pour les PTG PS?
“Wear often at post corners”

Osteolytic potential of the polyethylene debris



(Brown et al. *Comparison of Wear Particles Generated by Fixed and Rotating Platform Mobile Bearing Knee Designs*, accepted ORS 2005)

RP Advantage



- Increased Conformity
Reduced peak contact stress
- Reduced constraint
Reduced shear and self aligning

Fixation

Ciment / Sans ciment ...

Cemented fixation

Currently the gold standard

> 95% success rates at > 15 years FU



16 y

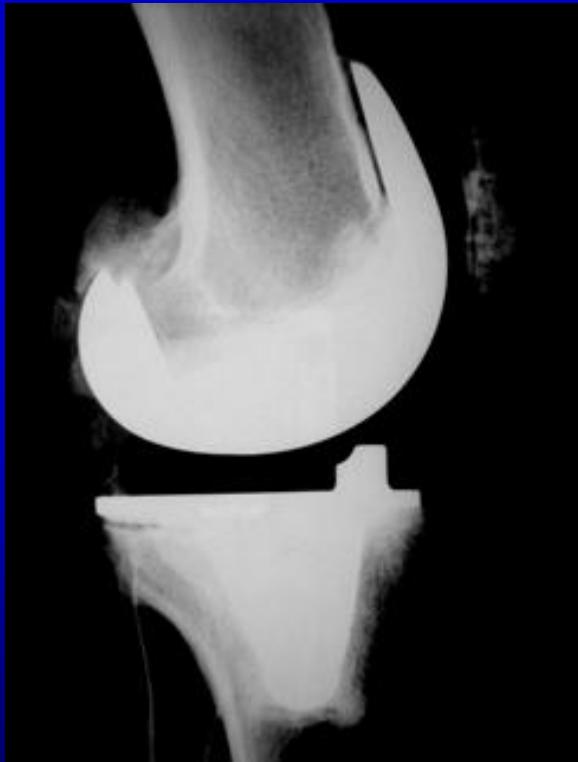


16 y

However...

Worse survivorship for younger patients (40-59 y-o)

≈ 85% success rates at 15 years FU in several series



♀ 59 yo
17 months po



Mechanisms of aseptic loosening

2 modes in cemented TKR:

- ✓ Failure related to osteolysis (polyethylene wear)
- ✓ Mechanical failure due to fragmentation and debonding of the cement mantle (implant/cement)

Why cementless TKR?

Need for more durable long term fixation
in younger and more active patients

- More biologically fixation method:
- ✓ Greater implants osseointegration
 - ✓ More iso-elastic behavior with adjacent bone

Long-term outcome of cementless TKR

Study	No. of patients	TKR	Type of cementless fixation	10-year survivorship
Buechel et al. CORR 2001	309	LCS (Depuy-Mitek)	Titanium porous-coated	97%
Hardeman et al. Knee 2006	115	Profix (Smith & Nephew)	Titanium porous-coated	97.1%
Hofmann et al. CORR 2001	176	Natural knee (Zimmer)	Titanium porous-coated (CSTi)	95.1%
Ritter et al. JOA 2009	73	AGC (Biomet)	Titanium porous-coated	97.2%
Epinette et al. JBJS Br 2007	74	Omnifit-HA (Osteonics)	Hydroxyapatite-coated	98.1%
Oliver et al. JBJS Br 2005	106	IB-II (Cresmacoli)	Hydroxyapatite-coated	94.9%
Cross et al. JBJS Br 2005	1000	Active TKR system (ASDM)	Hydroxyapatite-coated	99.14%

Cementless implants

Hydroxyapatite-coated implants

Highly porous metal

- ✓ Titanium porous-coated
- ✓ Porous tantalum



Osteoconductive materials

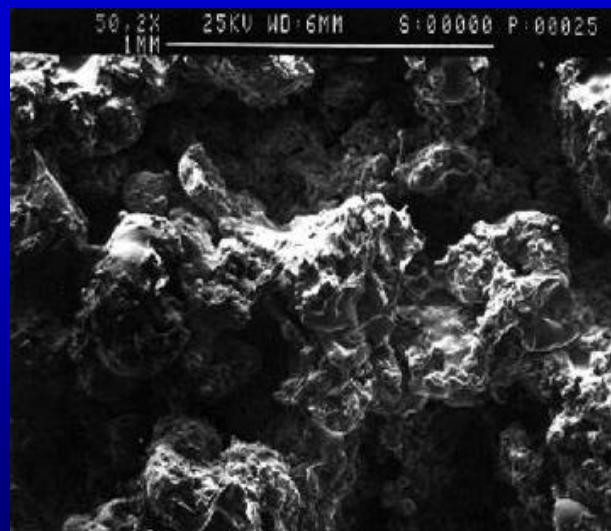
Hydroxyapatite-coated implants





HA-coating:

- ✓ Plasma-sprayed HA particles
- ✓ Roughened substrate surface



Optimal HA-coating:

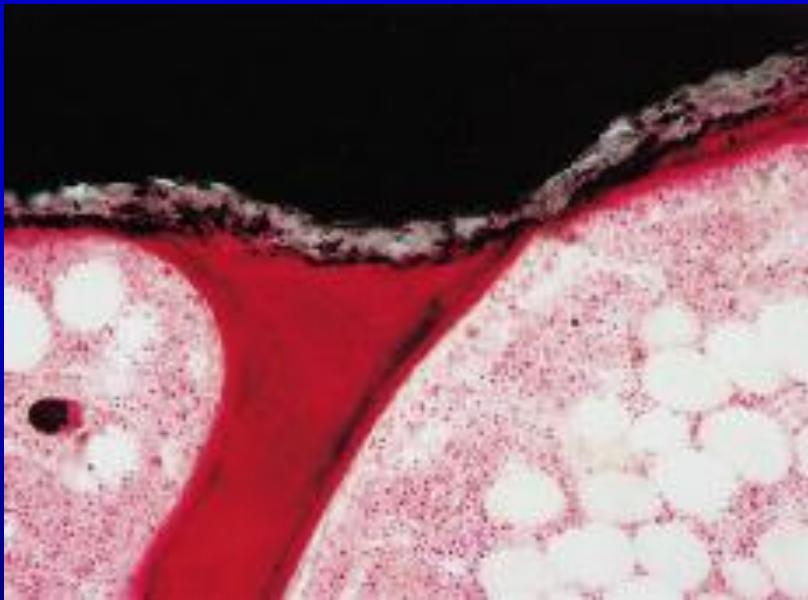
- ✓ High crystallinity and low porosity
(to avoid early dissolution)
 - ✓ Thickness $\approx 75 \mu\text{m}$
(to avoid fracture fatigue)

HA-coating:

Accelerate short-term bone apposition and ingrowth

Mechanisms:

- 1- Relative dissolution: release of calcium and phosphate
- 2- Initiation of osteoblastic activity
- 3- New bone formation at both bone and coating surfaces



2 weeks

HA-coating:

Enhancement of non-porous implants stability

Promotion of early bone ingrowth against implant

High success rate at 10 years FU

Prevention of PE particles ingress
due to interface implant / bone sealing

Porous-coated implants



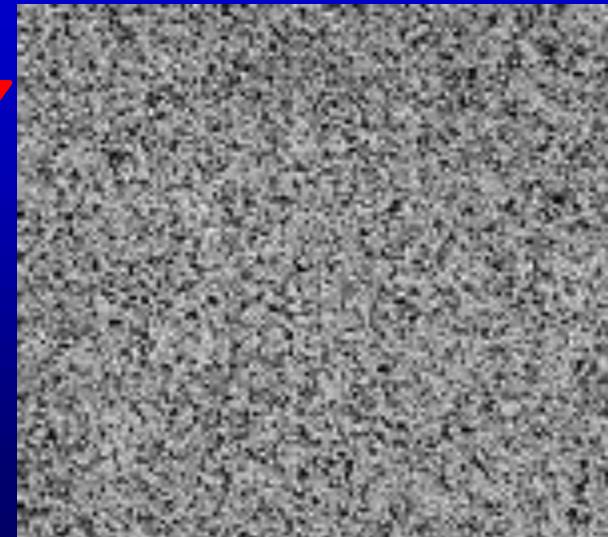
Titanium porous-coating: example of the CSTi® (Zimmer)

Pure titanium powder sintering onto CoCR alloy

Excellent biocompatibility of Ti

+

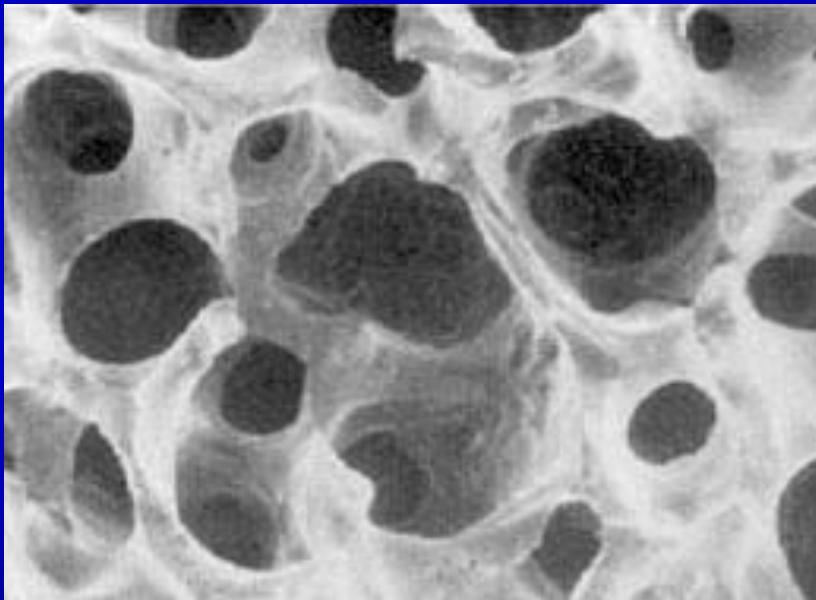
Optimal structure for bone ingrowth



Structure similar to trabecular bone

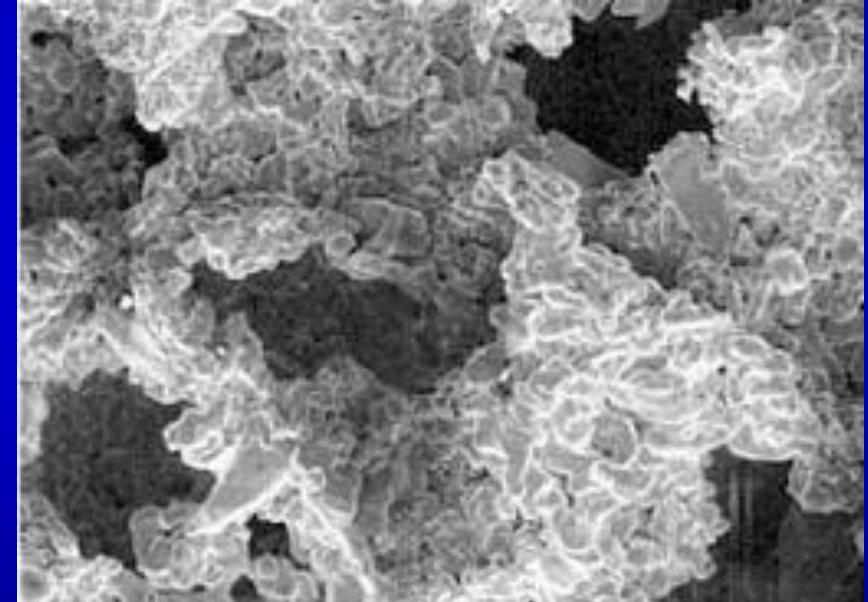
Interconnected pores network for bone ingrowth

Surface roughness providing adequate implant stability



Trabecular bone

Pore size = 400-500 μm
Pore volume = 60-77%

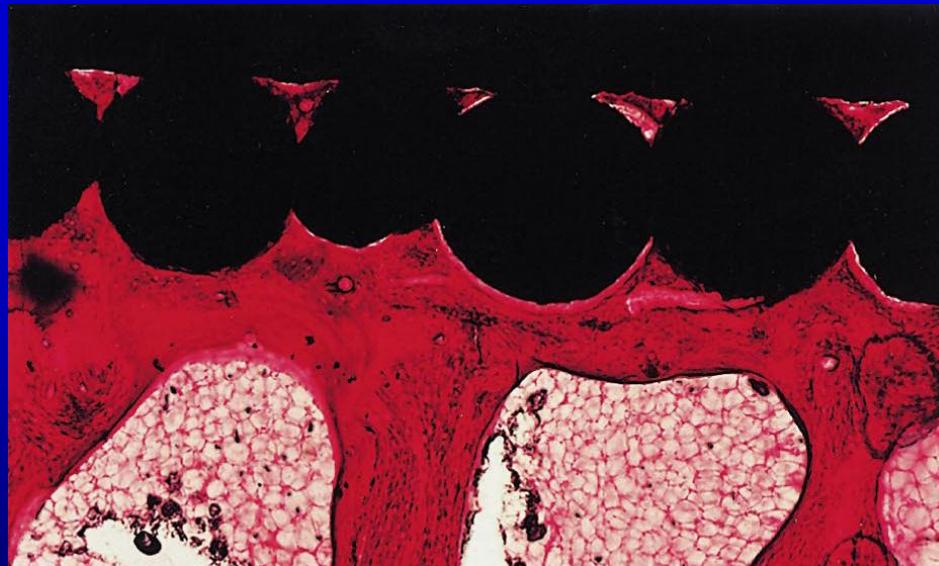


CSTi

Pore size = 480-560 μm
Pore volume = 45-68%

Mechanisms of bone ingrowth ≈ fracture healing process

- 1- Inflammatory process
with activation of osteo –blast and –clast cascade
- 2- Formation of woven bone at the interface into the pores
- 3- Remodeled to lamellar bone



48 months

Trabecular metal implants



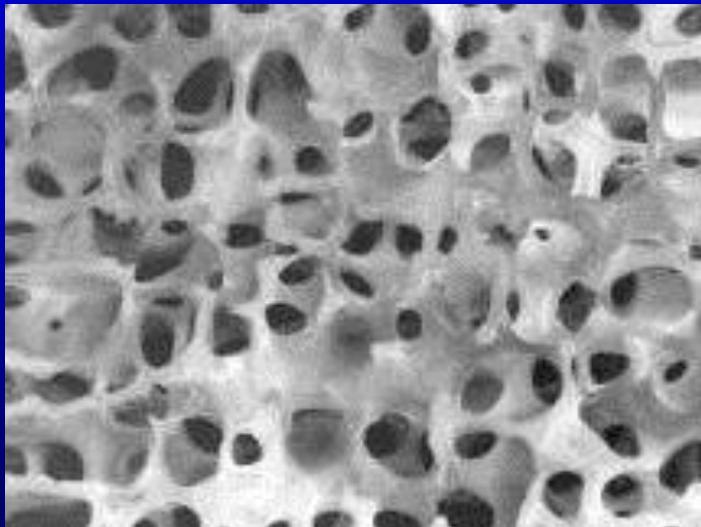
Tantalum (73Ta) =

Inert transition metal with excellent biocompatibility

Repeating dodecahedrons in an open-cell structure

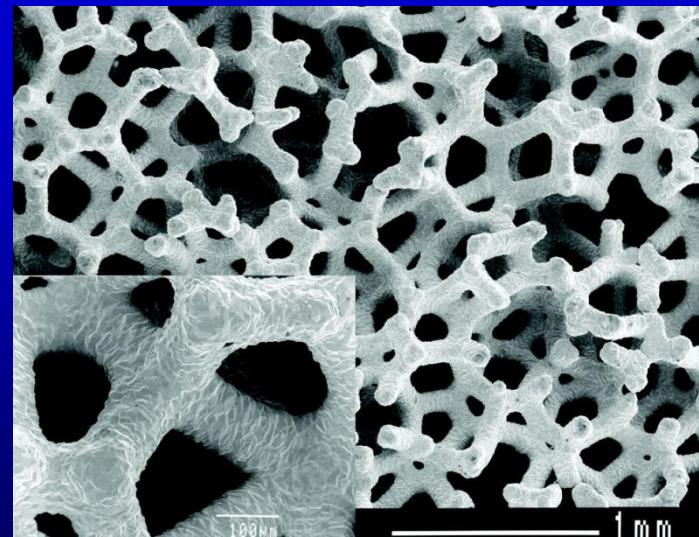
Trabecular metal characteristics:

- ✓ High volumetric porosity (> porous-coated implants)
- ✓ Low modulus of elasticity (> sub-chondral bone)
- ✓ High surface coefficient of friction



Trabecular bone

Bobyn JD et al. JBJS Br 1999

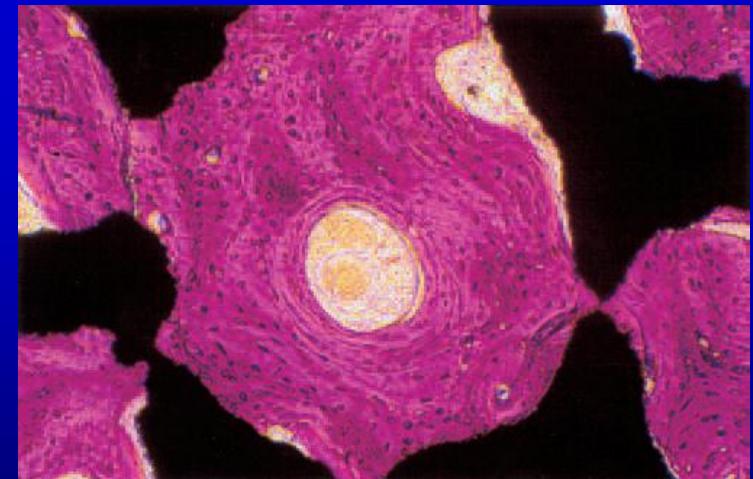
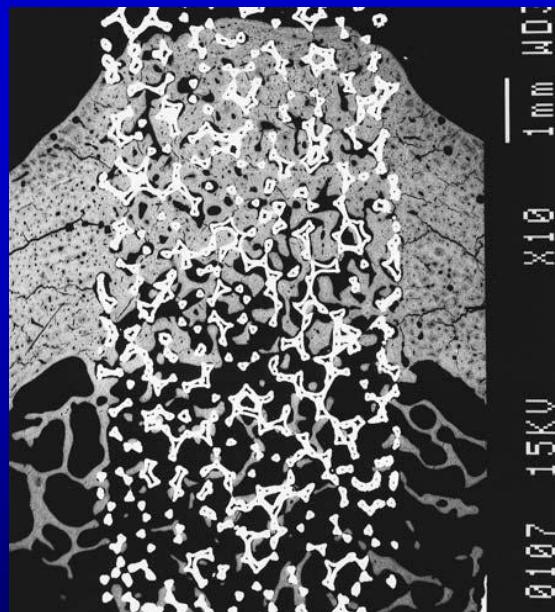


Trabecular metal

Canine model:

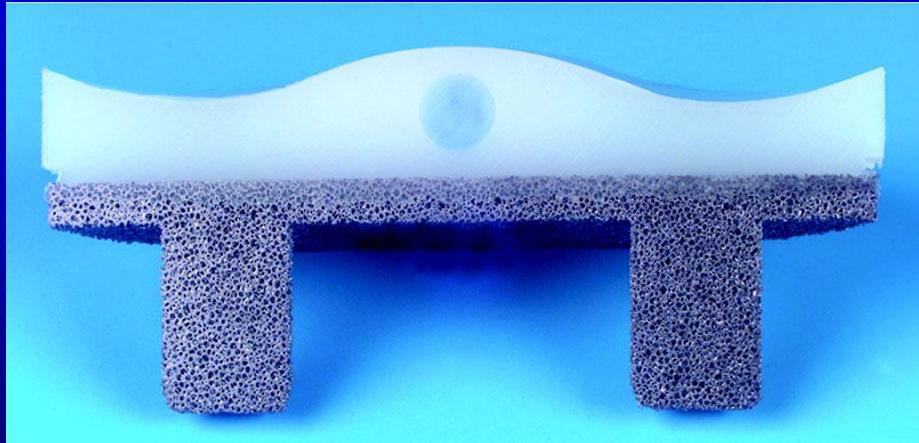
- ✓ New bone formation > 2/3 pores at 16 weeks
- ✓ Evidence of Haversian remodeling within the pores at 52 weeks
- ✓ Complete host bone incorporation at 1 year after implantation

Direct bonding to bone with excellent bone in-growth



Primary TKR = Monoblock tibial component (Zimmer)
Compression molded UHMW-PE bearing surface

Early encouraging results in prospective multicenter study
72 implants at \approx 2 years FU :
No radiolucent lines
No revisions



Take Home Message

- Connaître l'histoire des PTG
- Comprendre la biomécanique
- Choisir la ou les meilleures options

