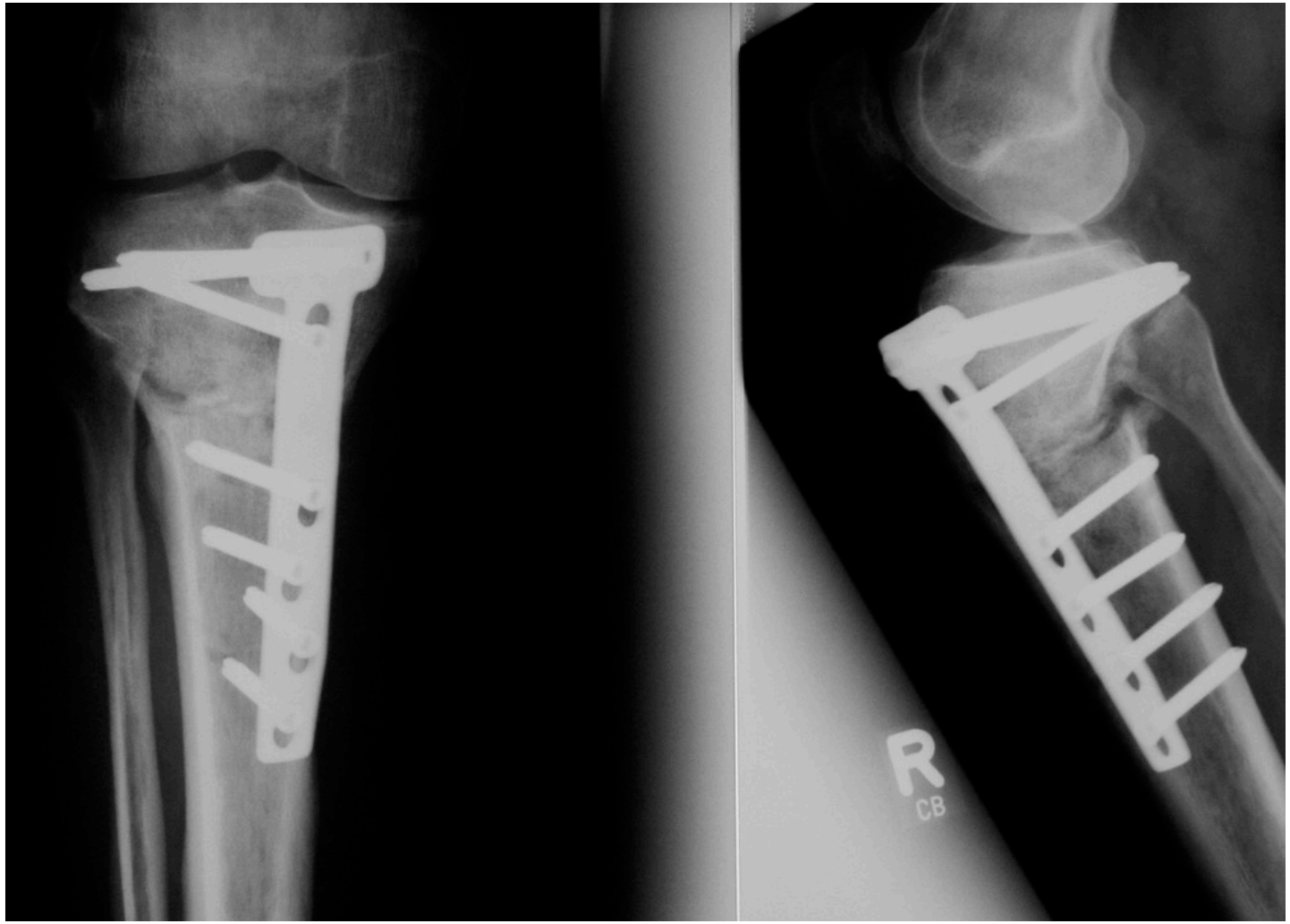
Tibial Slope

What is the Slope??

Hinge breaking
+
Breaking of
2 screws distally
+
Slope increased

➢ Revision by reducing slope



Slope History

CW HTO Results 2001

Unexpected change of slope

Slope	
- preoperative	ø 6,2° (0°-12°)
- 6w postoperative	ø 1,5° (10°- (+6°)
Valgus change	
- effective	ø 4,9° (2-12)
- planned	ø 7,6° (5°-14°)

Agneskirchner JD et al., Arch Orthop Trauma Surg, 2004
Imhoff AB et al., Orthopäde, 2004
Giffin et al., Am J Sports Med, 2004

CW HTO Results 2001

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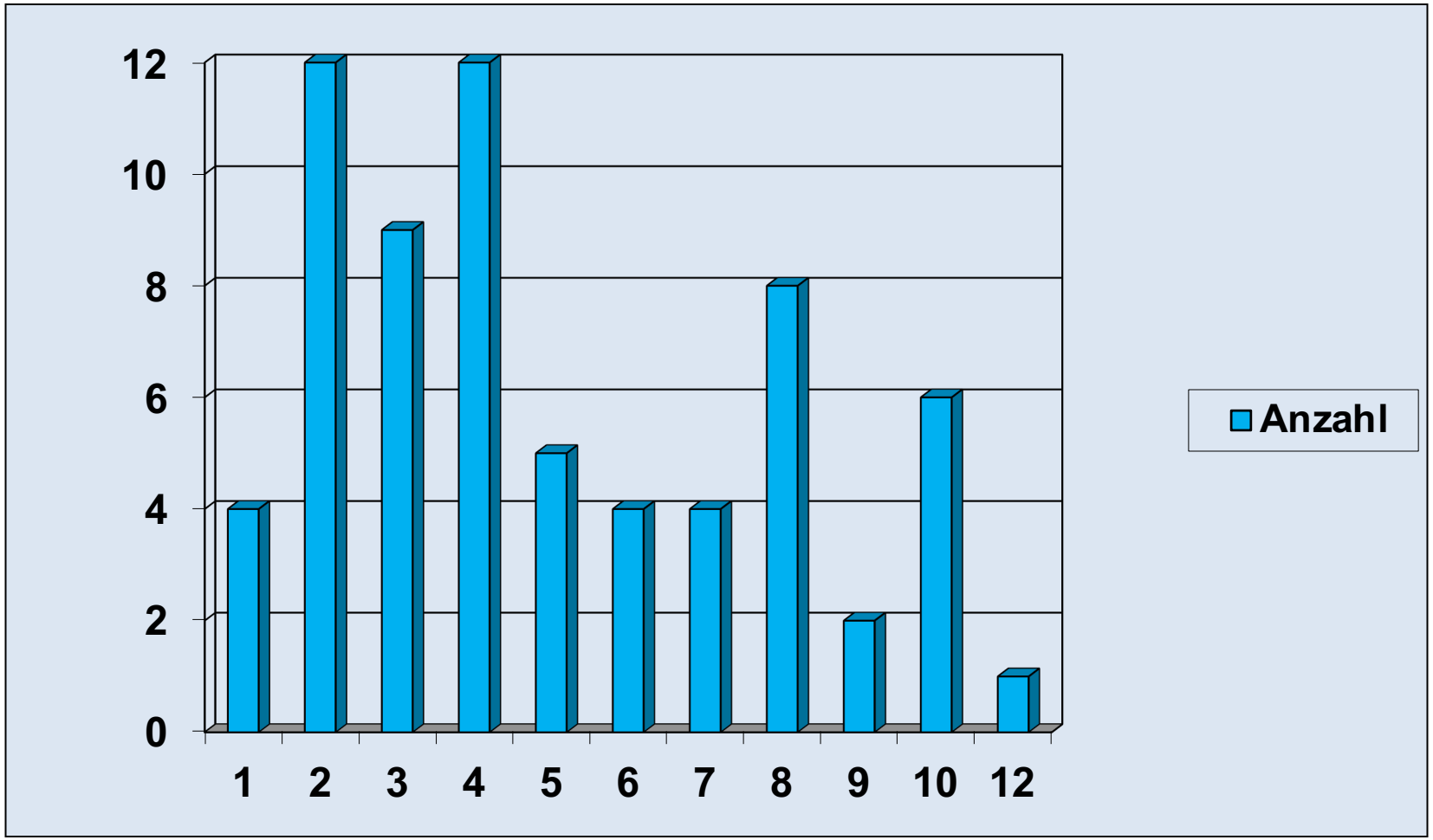
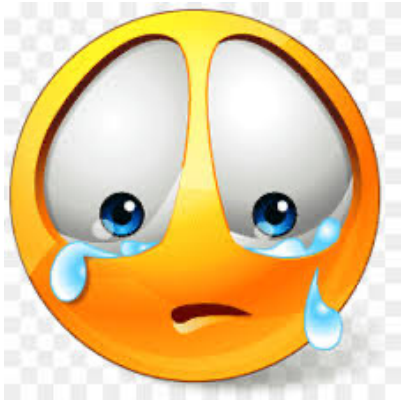
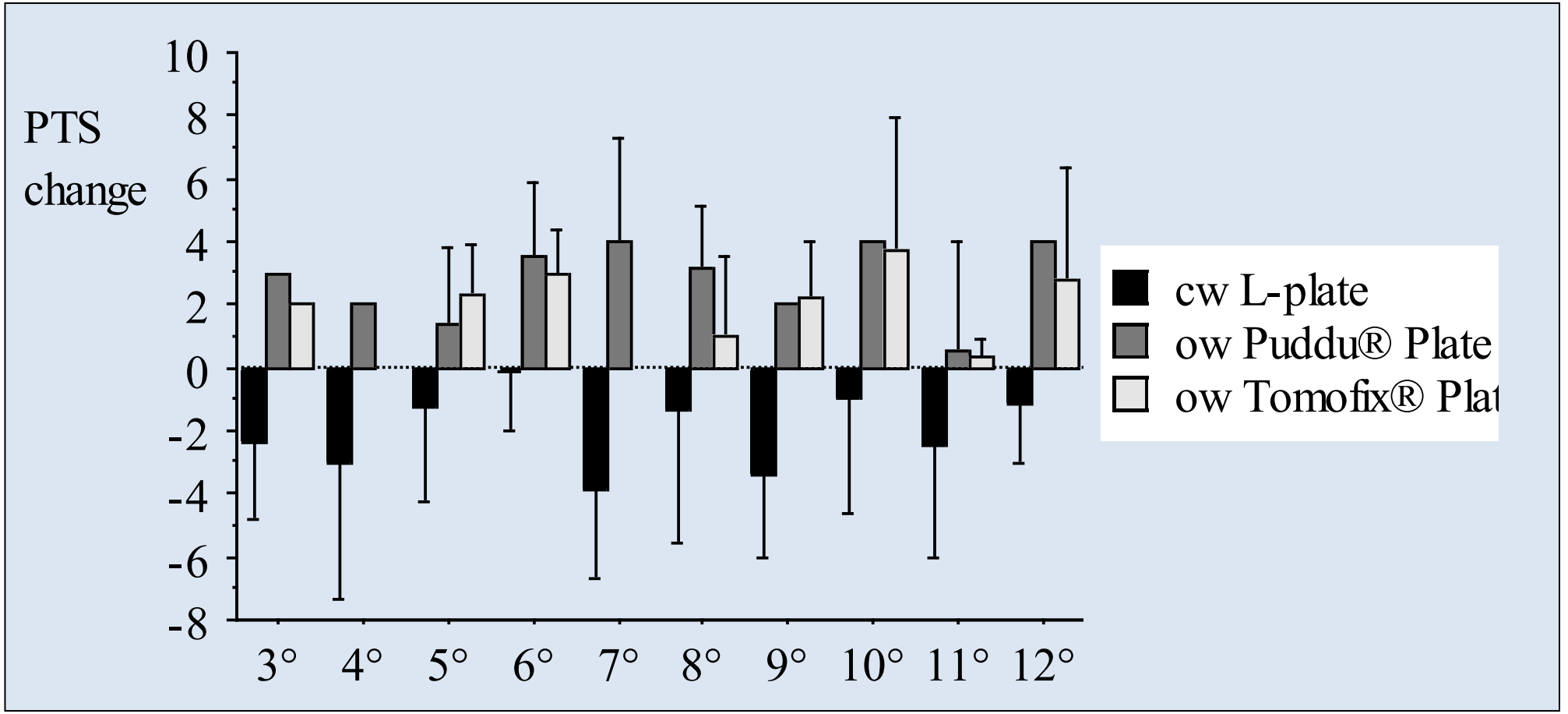
Unexpected change of slope





Ow vs cw HTO: change of slope

Unexpected change of +/- slope



El-Azab H, Imhoff AB, Hinterwimmer S. JBJS Br 2008

TIBIAL TRANSLATION AFTER ANTERIOR CRUCIATE LIGAMENT RUPTURE

TWO RADIOLOGICAL TESTS COMPARED

HENRI DEJOUR, MICHEL BONNIN

"When weight-bearing, **every 10° in tibial slope is associated with 6mm in anterior tibial translation**, both in normal knees and those with a ruptured ACL, but the magnitude of displacement is greater in the latter!"

JBJS 1994

High Posterior Tibial Slope (PTS)

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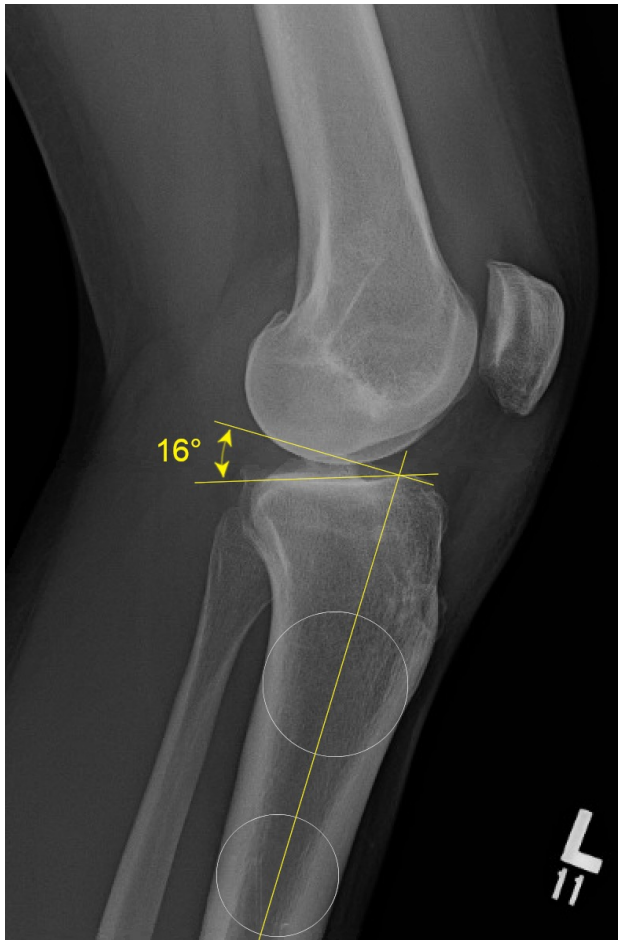
Clinical Observations

- Primary ACL injuries
- Single and multiple ACL graft failures
- Medial meniscus tears
- Postero-medial and postero-lateral meniscal root tears

Liu et al. KSSTA. 2022.
Jiang et al. Arthroscopy. 2022.
Winkler et al. KSSTA 2021.
Moon et al. AJSM. 2020.
Hiranaka et al. KSSTA. 2020.
Grassi et al. AJSM. 2019.
Kolbe et al. KSSTA. 2019.



What is the cause for these observations?

Systematic Review (Liu et al. KSSTA. 2022.)

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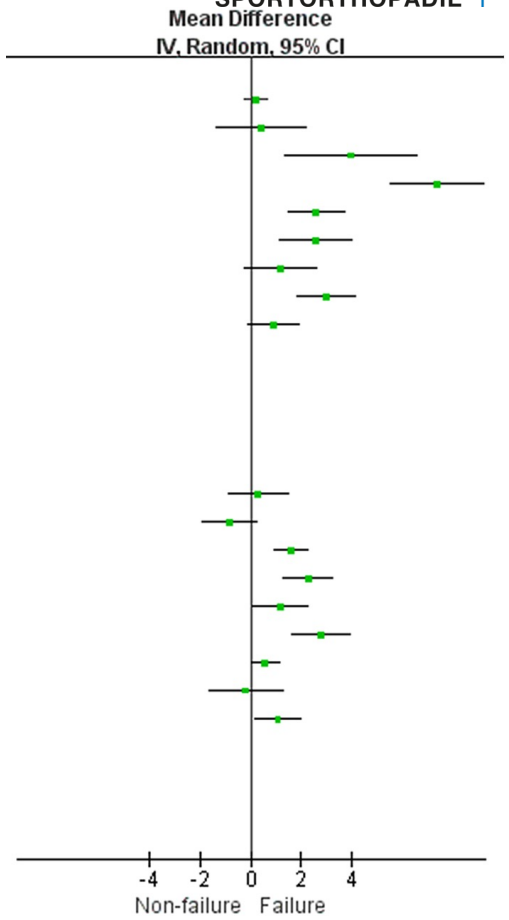
- Association between PTS and ACL graft failure
- Included studies: **20**
- Included patients: **5326**
- **CAVE:** Additional risk factors were not considered

	Failure	Non-Failure
Medial PTS, [°]	4.71 – 17.2	3.5 – 14-4
Lateral PTS, [°]	5.5 – 13.3	2.9 – 11.9



Mean difference in medial PTS between failure and non-failure

Increased PTS = higher risk of ACL graft failure

The American Journal of Sports Medicine
2021;49(3):620–625
DOI: 10.1177/0363546520982241
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VIDEO Abstract

Posterior Tibial Slope in Patients Undergoing Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autograft

Analysis of Subsequent ACL Graft Tear or Contralateral ACL Tear

K. Donald Shelbourne,* MD, Rodney W. Benner,* MD, Jonathan A. Jones,* and Tinker Gray,*† MA
Investigation performed at Shelbourne Knee Center at Community East Hospital, Indianapolis, Indiana, USA

The American Journal of Sports Medicine
aossm™ American Orthopaedic Society for Sports Medicine

Methods

- 3292 patients total 2913 primary ACLR 379 revision ACLR
- single center
- 3 surgeons
- prospektive follow up (2001-2015) until rerupture or contralat. rupture
- annual questionaire by email
- min. follow up 4 y

Age

TABLE 1
Age at Surgery by Group[a]

Group (n)	Age at Surgery, y	*P* Value[b]
Primary surgery (2439)		
Graft tear (126)	19.2 ± 6.3	<.001
Contralateral ACL tear (85)	17.9 ± 10.1	<.001
No tear (2228)	24.7 ± 10.3	
Revision surgery (324)		
Graft tear (19)	22.9 ± 8.7	.457
Contralateral ACL tear (6)	24.6 ± 10.0	.960
No tear (299)	24.4 ± 8.8	

[a]Data are presented as mean ± SD. ACL, anterior cruciate ligament.
[b]*P* value for age at surgery between the tear and no-tear groups.

Px with rerupture or contralateral rupture are signifikant younger than Px without rerupture after ACLR

Results

TABLE 3
Rate of Subsequent Tear Based on PTS Group[a]

Group	No.	Graft Tear, n (%)	Contralateral ACL Tear, n (%)
Primary surgery			
PTS ≤9°	2254	108 (4.8)	76 (3.4)
PTS ≥10°	185	18 (9.7)	9 (4.9)
P value		.003	.287
Revision surgery			
PTS ≤9°	292	17 (5.8)	5 (1.7)
PTS ≥10°	32	2 (6.3)	1 (3.1)
P value		.922	.574

[a]ACL, anterior cruciate ligament; PTS, posterior tibial slope.

Significantly higher rate of rerupture if slope ≥10°.

Not contralateral and not in revision

Measurement of the Posterior Tibial Slope Depends on Ethnicity, Sex, and Lower Limb Alignment

A Computed Tomography Analysis of 378 Healthy Participants

Corentin Pangaud,*†‡ MD, Pierre Laumonerie,§‖ MD, Louis Dagneaux,†‡ MD, Sally LiArno,¶ PhD, Peter Wellings,¶ MSc, Ahmad Faizan,¶ PhD, Akash Sharma,†‡ MBBS, FRCS, and Matthieu Ollivier,†‡ MD, PhD

Investigation performed at St Marguerite Hospital, Marseille, France

OJSM 2020

- 378 patients
- Medial PTS: 6.3° (range, **–5.5° to 14.7°** ; 1% with >12°)
- lateral PTS: 6.2° (range, **–4.1° to 17.2°** ; 3% with >12°)

Increased Radiographic Posterior Tibial Slope Is Associated With Subsequent Injury Following Revision Anterior Cruciate Ligament Reconstruction

Richard J. Napier,* MB BCh BAO, Msc(Ed), FRCS, Enrique Garcia,† MD,
Brian M. Devitt,† MD, FRCS, FRACS, Julian A. Feller,† FRACS, and Kate E. Webster,‡§ PhD

Investigation performed at OrthoSport Victoria and La Trobe University, Melbourne, Australia

Orth J Sports Med 2019

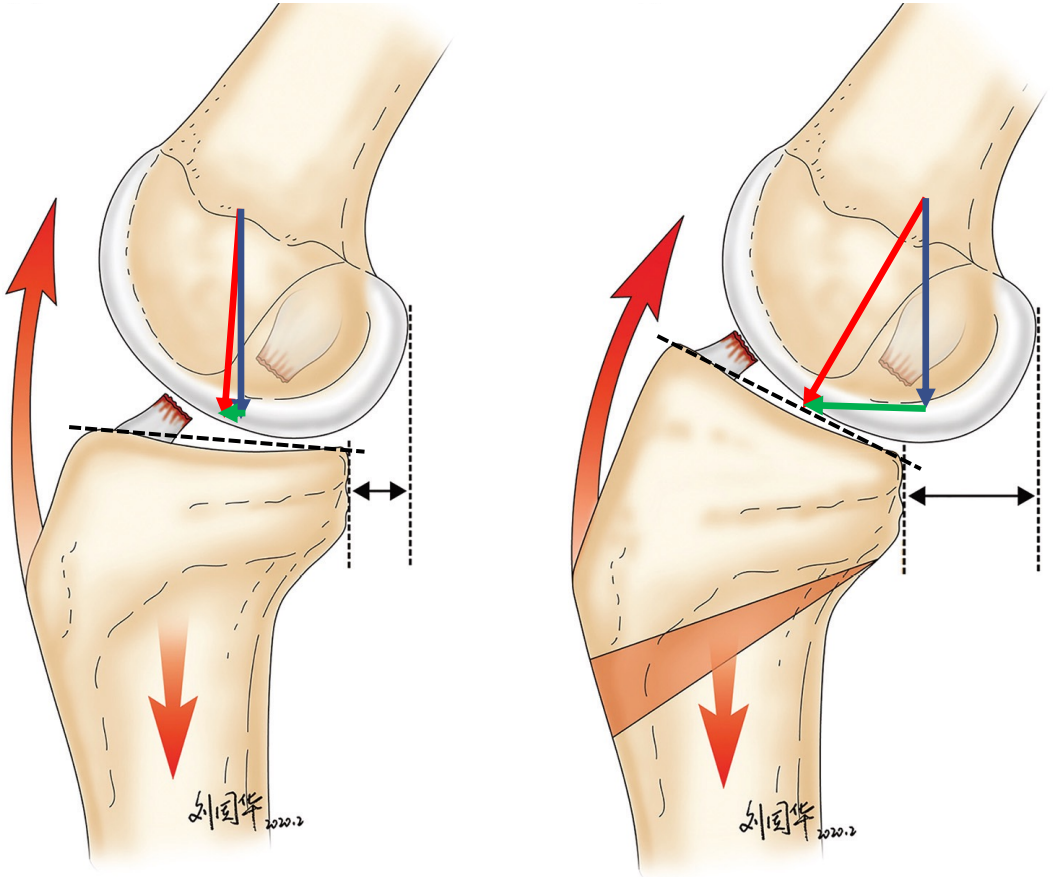
- 330 patients, retrospective cohort study
- Medial: 7.5° vs 6.3° [p = .01]; lateral, 13.6° vs 11.9° [p = .001]
- "**Increased posterior tibial slope**,…, was associated with **increased risk of graft rupture and contralateral ACL injury** after revision ACL reconstruction.

Biomechanics

ACL insufficiency + high PTS

- Anterior tibial translation
- Proximal tibial translation

Imhoff et al. AJSM. 2020.
Yamaguchi et al. AJSM. 2017.

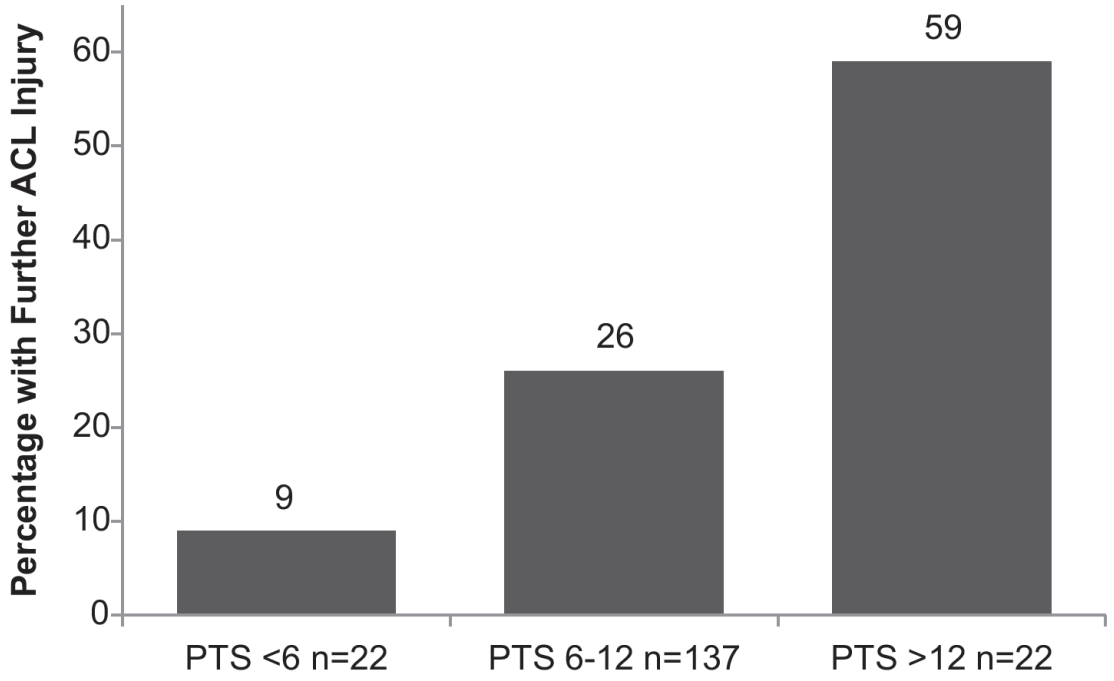


Song et al. AJSM. 2020.

Tibial slope affects knee kinematics and ACL graft forces

Posterior Tibial Slope and Further Anterior Cruciate Ligament Injuries in the Anterior Cruciate Ligament–Reconstructed Patient

Prospective 15 year follow-up of 200 ACL reconstructions



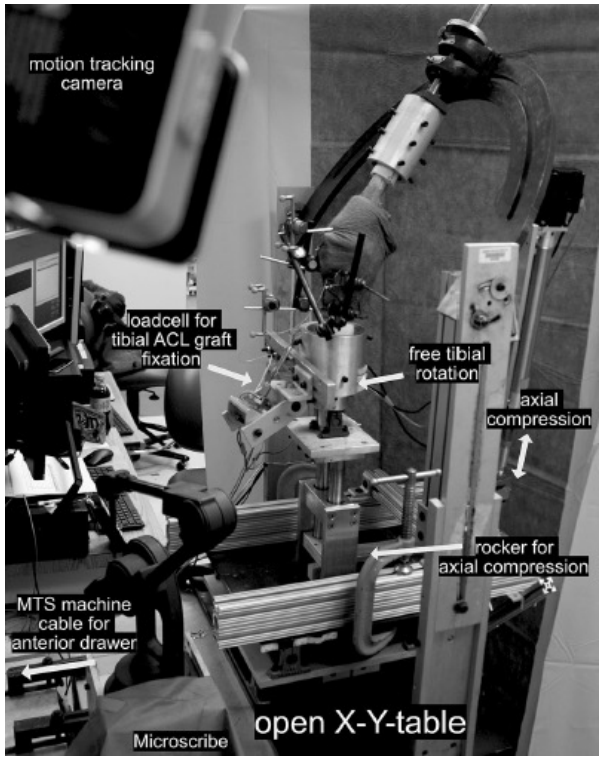
59%

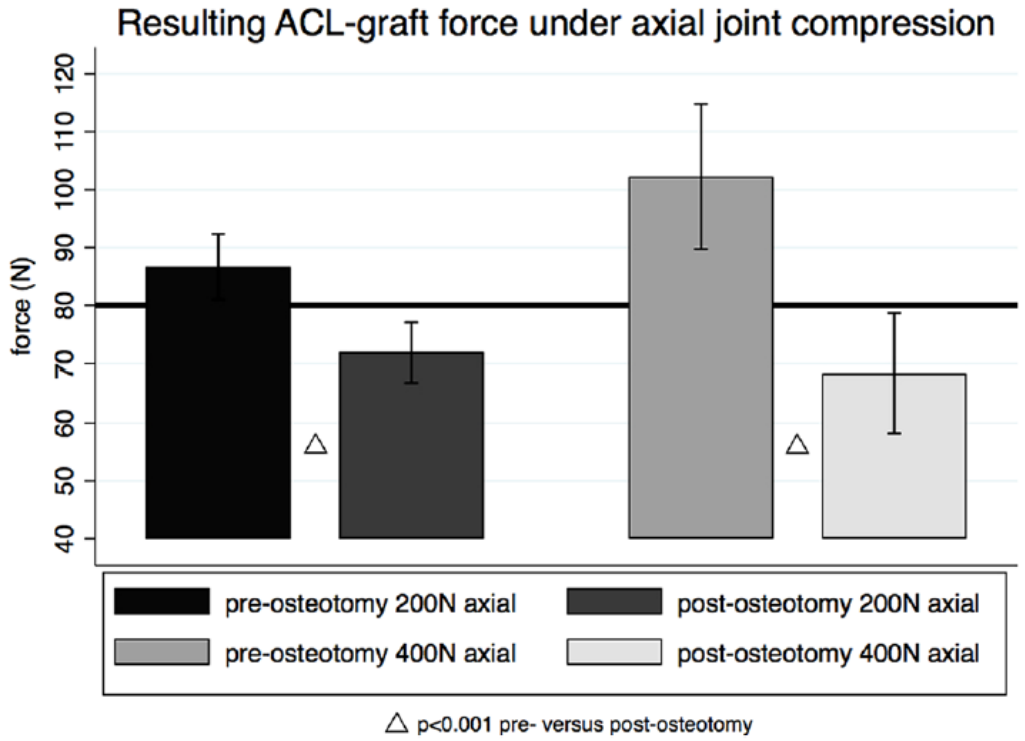
5-fold increased risk for further ACL injury in patients with tibial slope > 12°

Webb et al. (2013) Am J Sports Med

Slope-reducing tibial osteotomy decreases ACL-graft forces and anterior tibial translation under axial load

Florian B. Imhoff[1,2] · Julian Mehl[1,2] · Brendan J. Comer[2] · Elifho Obopilwe[2] · Mark P. Cote[2] · Matthias J. Feucht[1] · James D. Wylie[2,3] · Andreas B. Imhoff[1] · Robert A. Arciero[2] · Knut Beitzel[1,2]





Imhoff F. et al. (2019) Knee Surg Sports Traumatol Arthrosc

Slope-reducing tibial osteotomy decreases ACL-graft forces and anterior tibial translation under axial load

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"**Slope-reducing osteotomy decreased anterior tibial translation** in the ACL-deficient and ACL-reconstructed knee under axial load"

"Especially in ACL revision surgery, the **osteotomy protects the reconstructed ACL with significantly lower forces** on the graft under axial load"

KSSTA 2019

Technique
Tricks + Tipps

Control of Slope und Torsion

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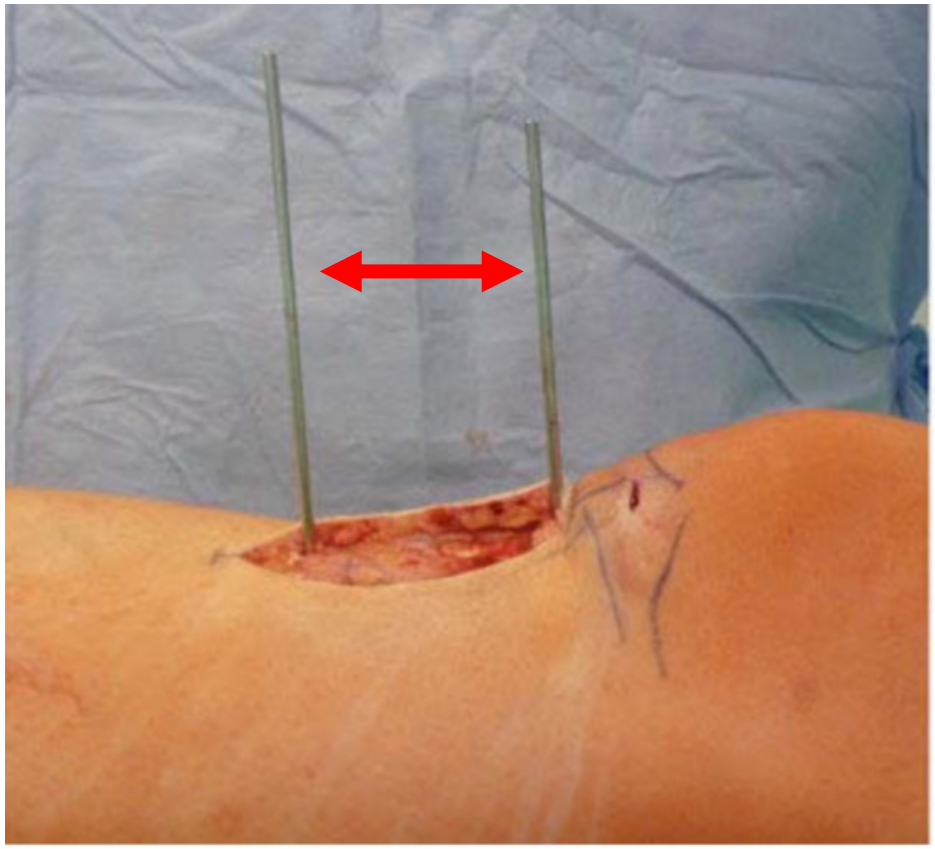

Slope increasing
ca. 4 degree

Internal torsion
increasing
ca. 5 degree

while 7° Varus

Control of posterior tibial slope and patellar height in open-wedge valgus high tibial osteotomy.
Hinterwimmer S, Beitzel K, Paul J, …..Imhoff AB. *Am J Sports Med. 2011;39:851-6*

OW technique: Gap filling ?/!

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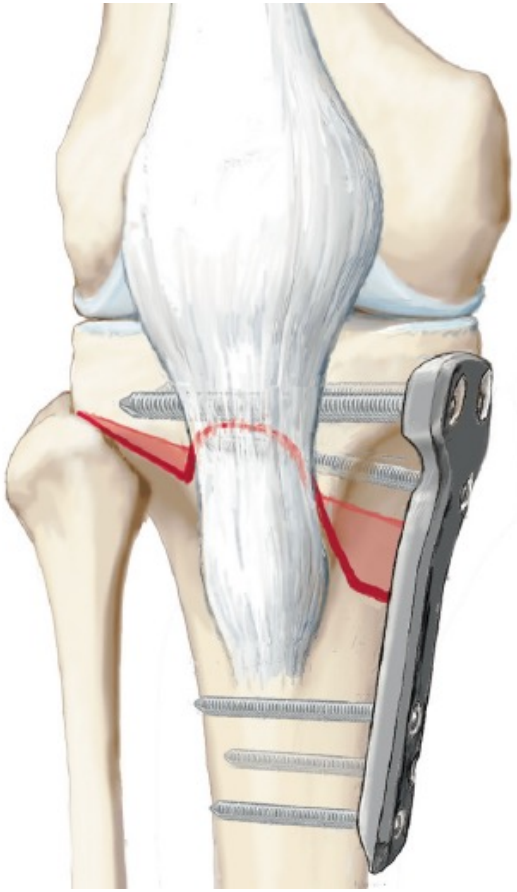
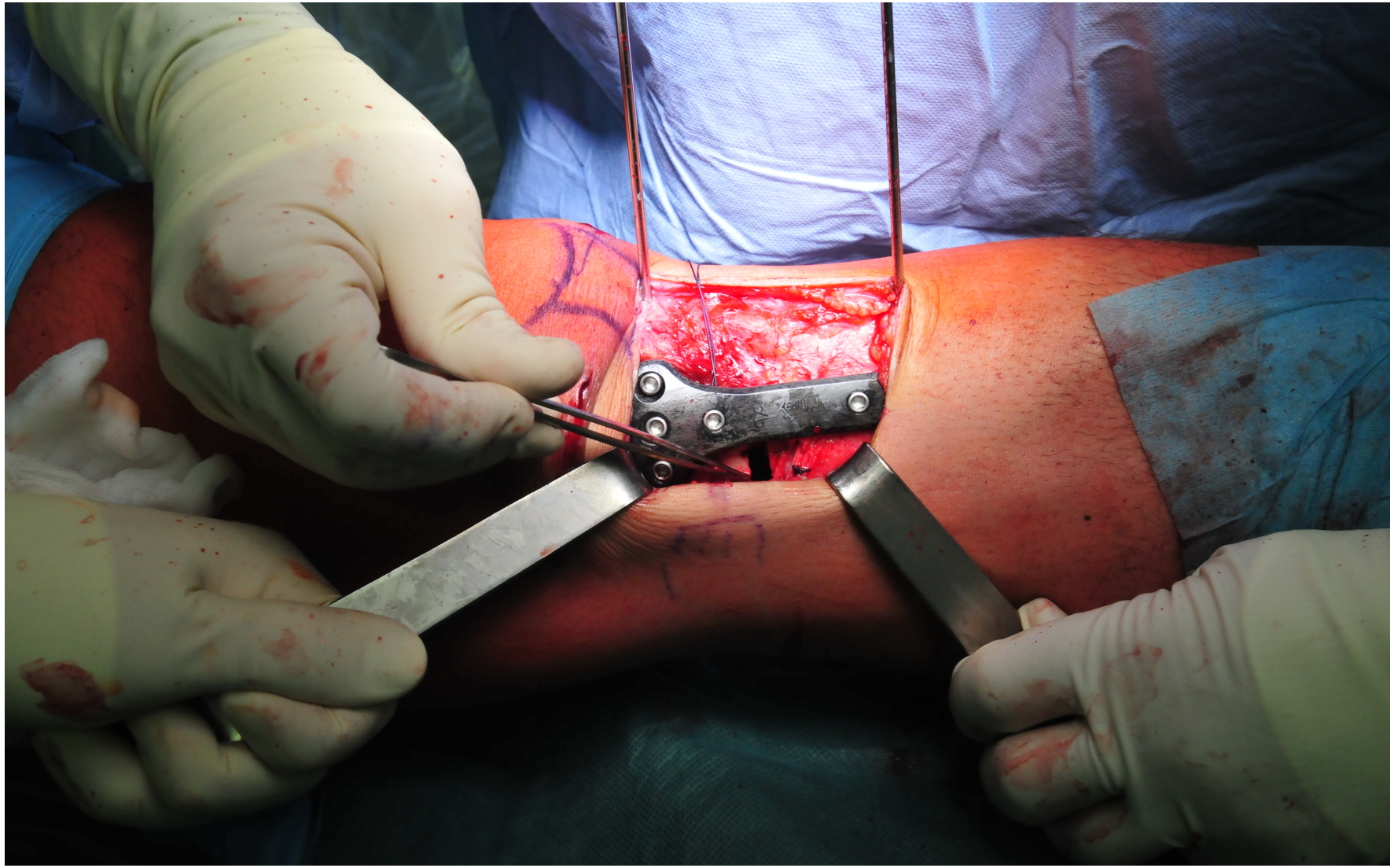
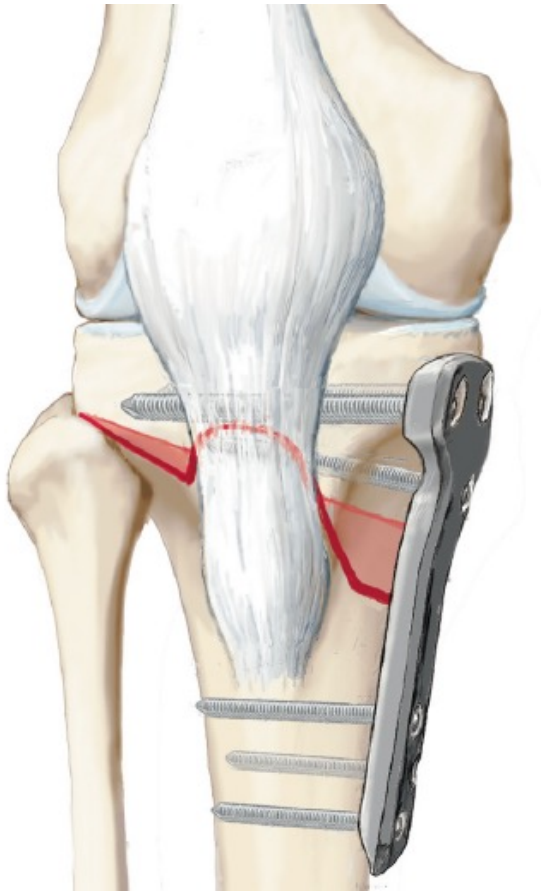
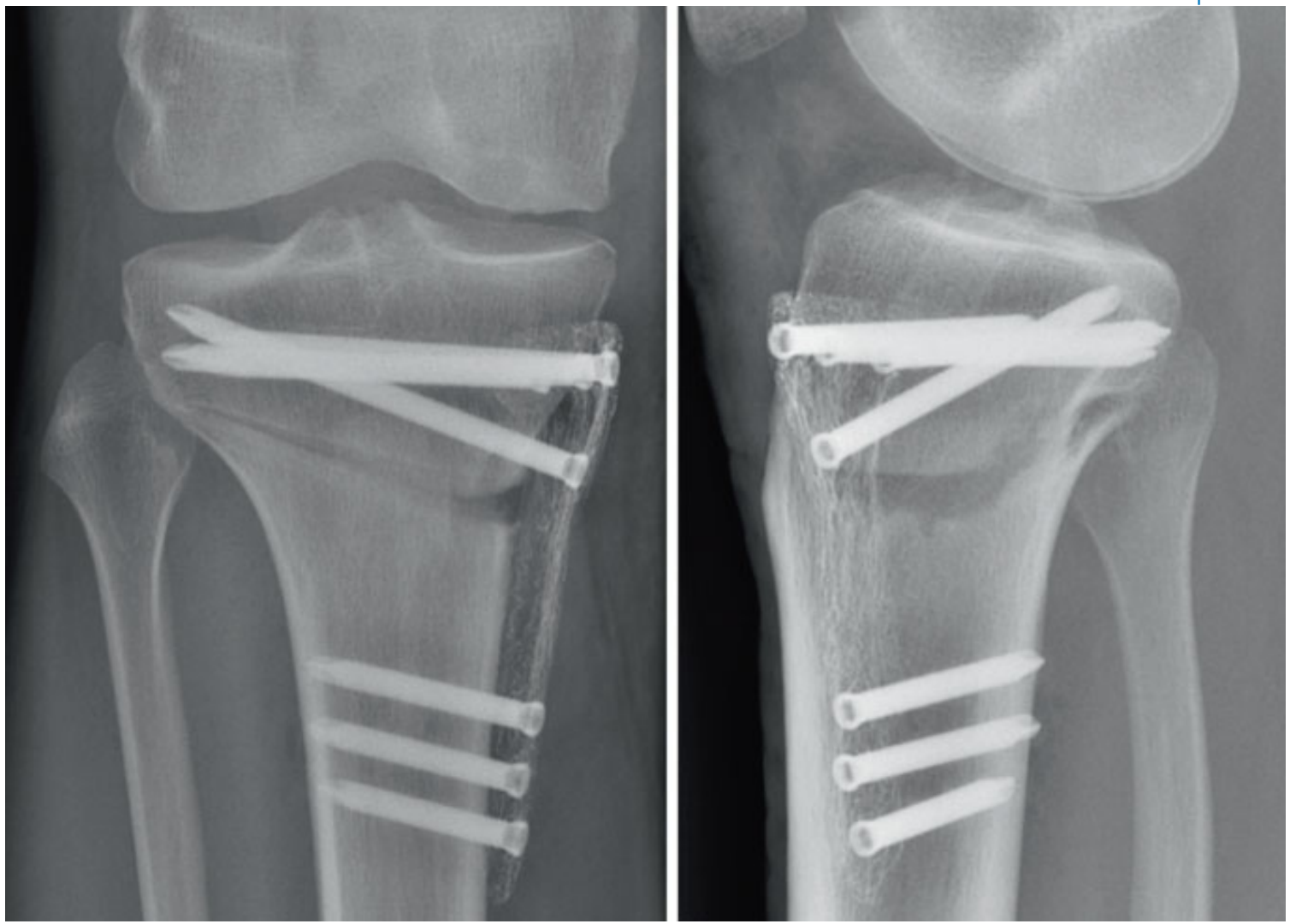


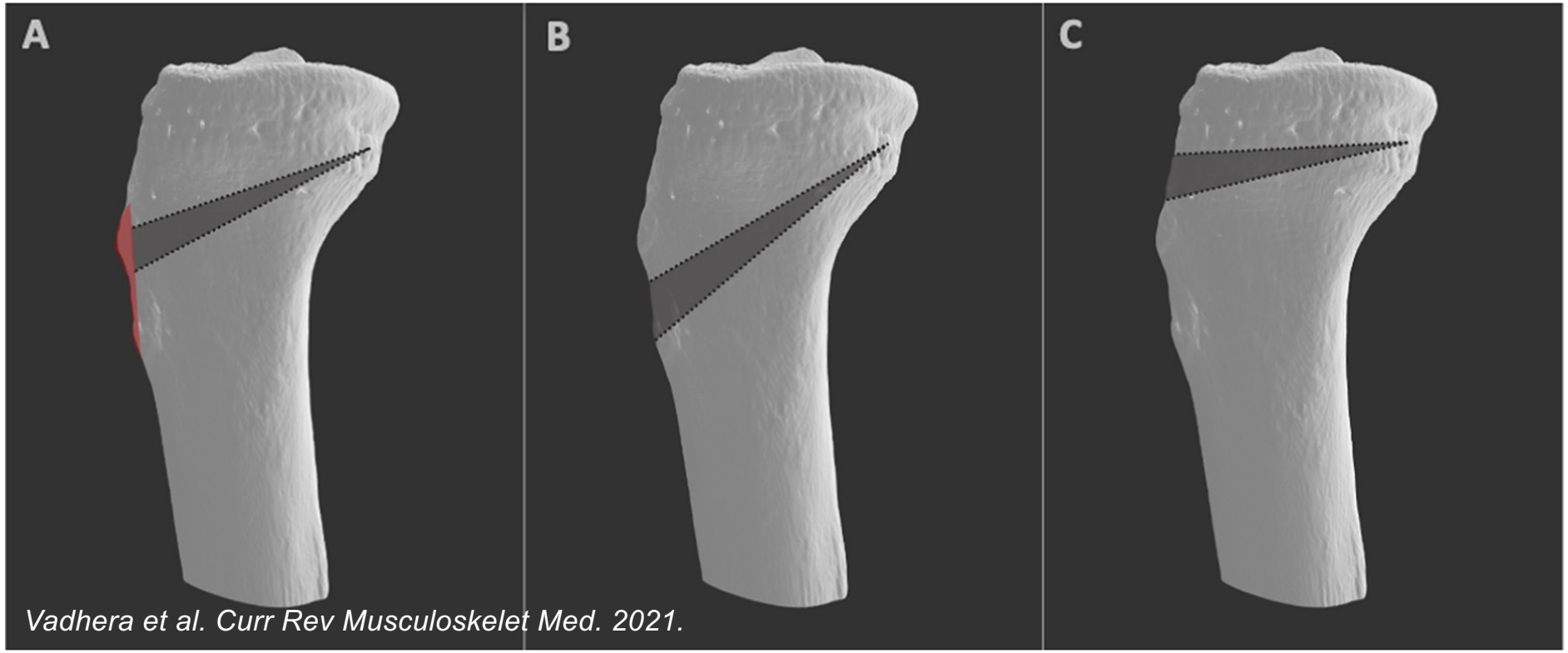


OW technique: X-ray control





Techniques

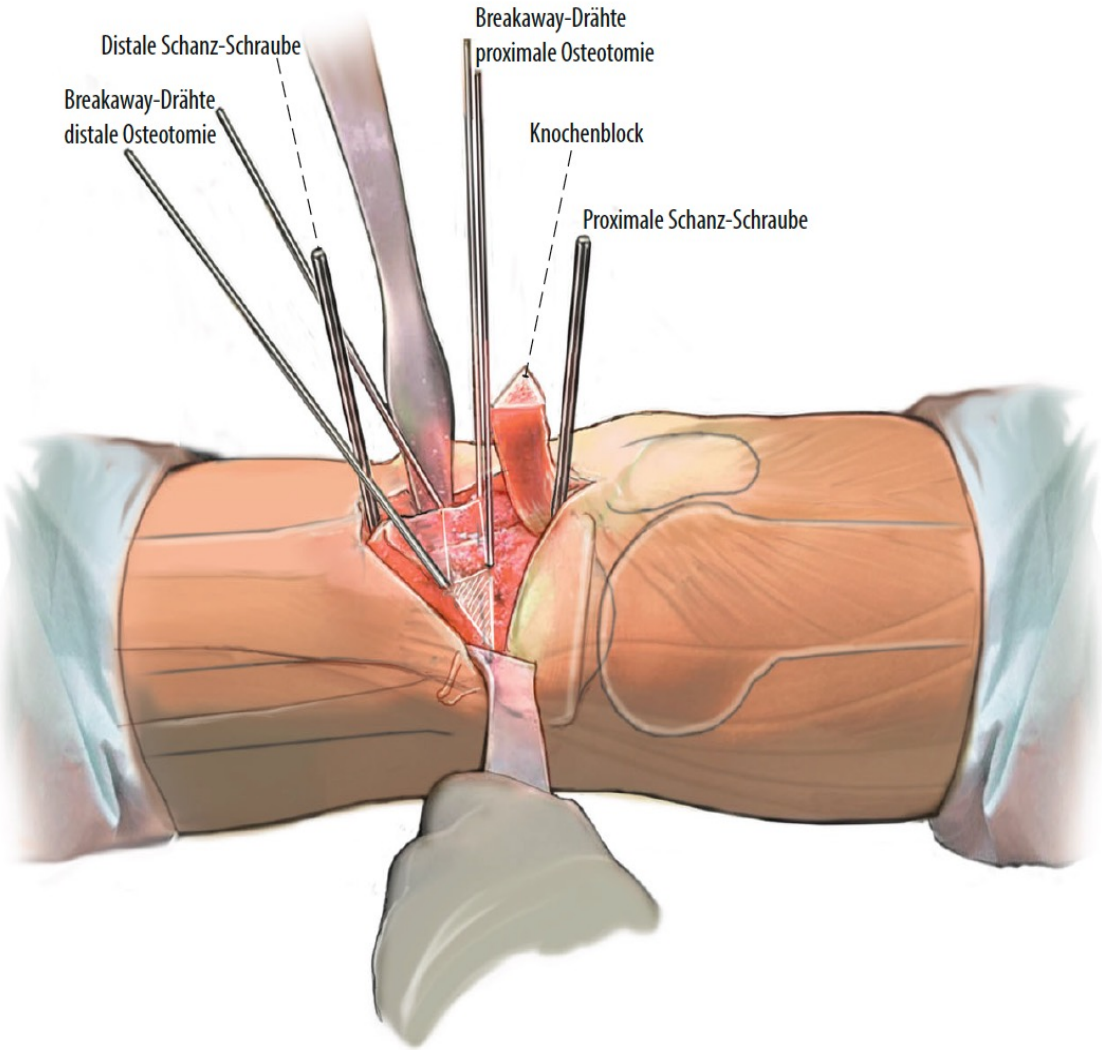


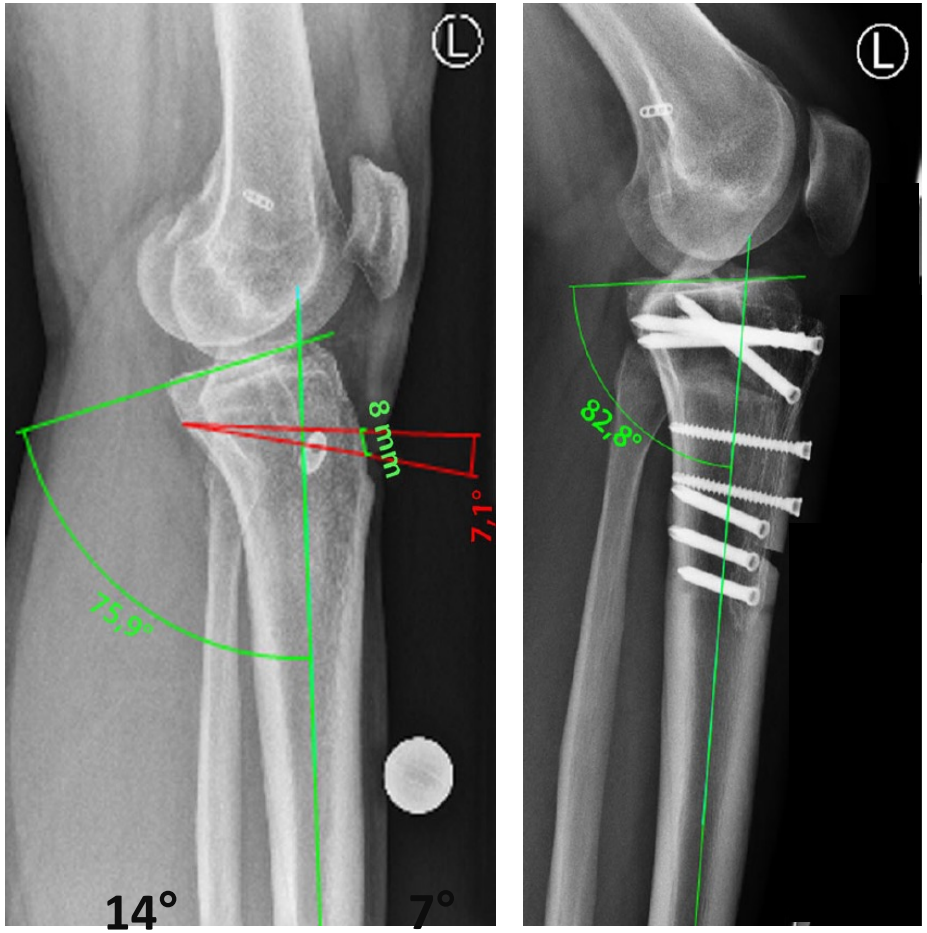
Vadhera et al. Curr Rev Musculoskelet Med. 2021.

Transtuberositary **Infratuberositary** **Supratuberositary**

The patellofemoral joint is a key factor in determining the surgical approach

Slope modifying Osteotomy – anterior cw + medial ow + tuberosity OT





Diermeier, Imhoff, Beitzel (2017) Oper Orthop Traumatol

My Technique – Posterior Cortical Hinge

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- Tibial insertion of PCL
- **CAVE:** Popliteal artery
- Guided by K-wires
- Confirmed by fluoroscopy

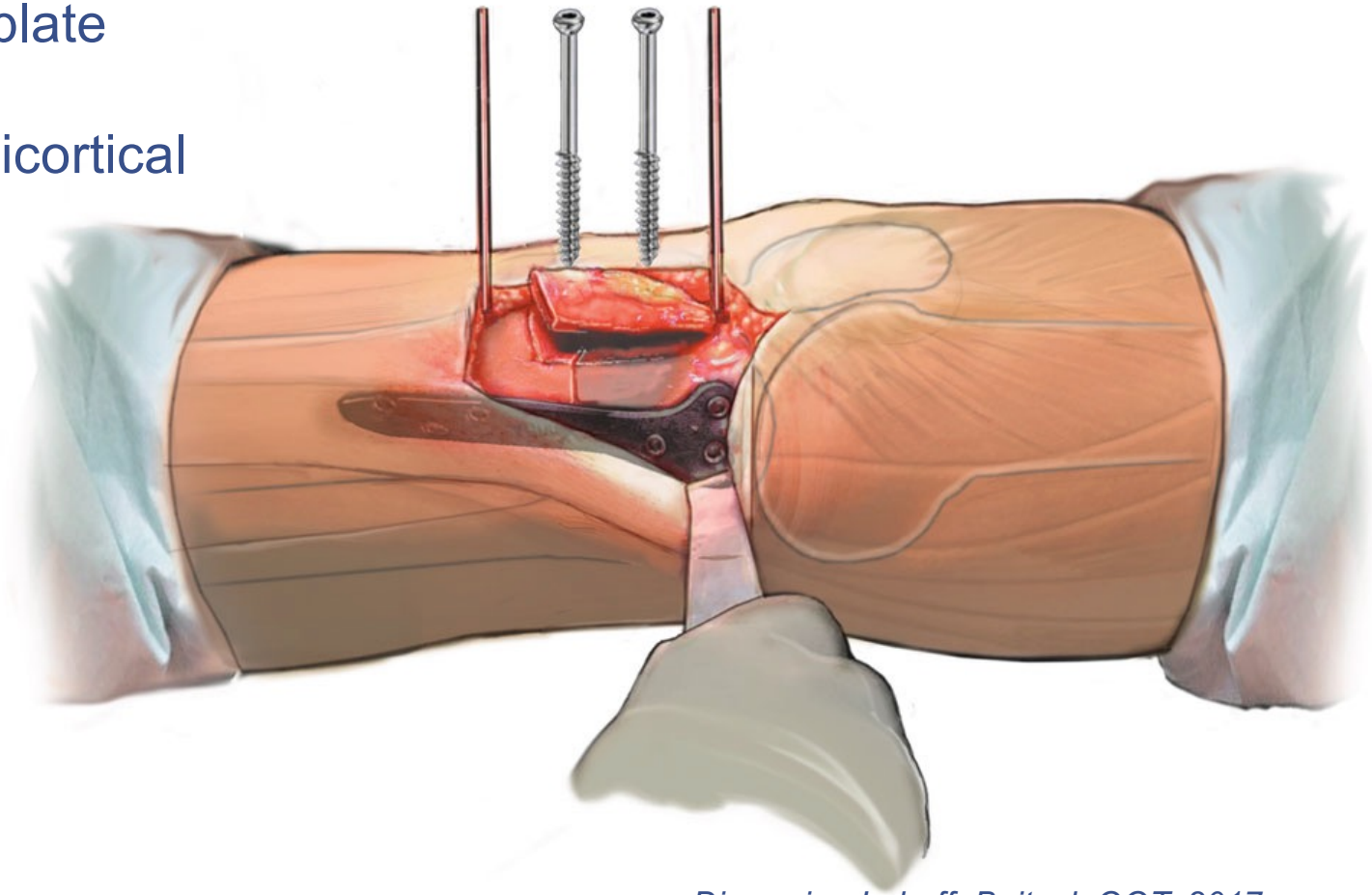
Demonstration (laboratory study)

© Winkler PW

Intact hinge is a key element

My Technique – Fixation

- Locking compression plate
- Tuberosity fixed with bicortical screws



Diermeier, Imhoff, Beitzel. OOT. 2017.

Tibial bone block needs to be adjusted to maintain patellofemoral alignment

Case I

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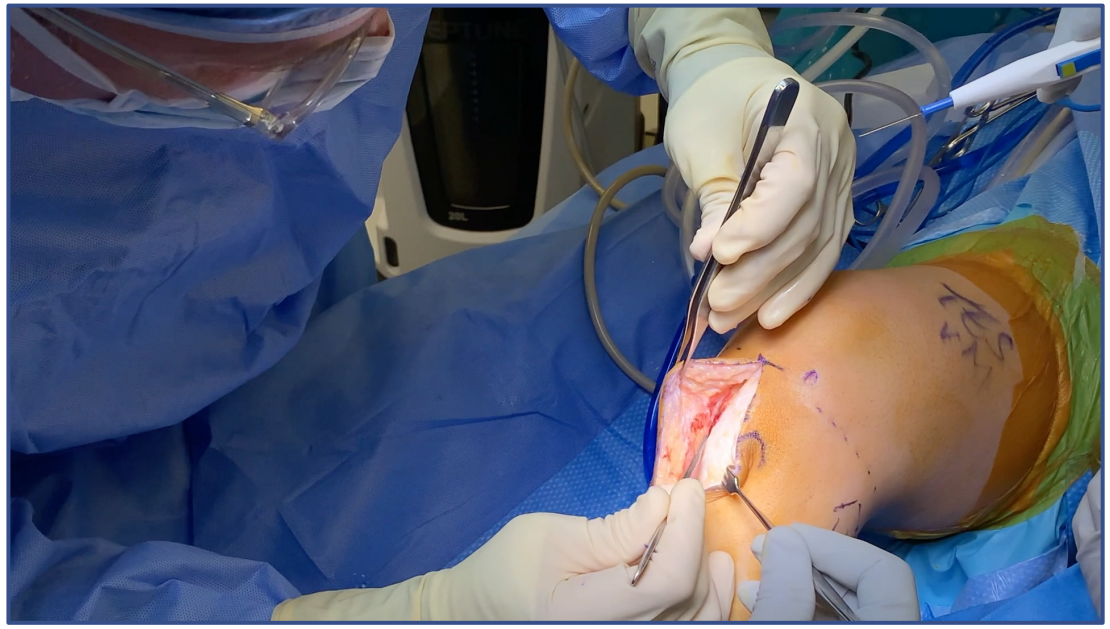
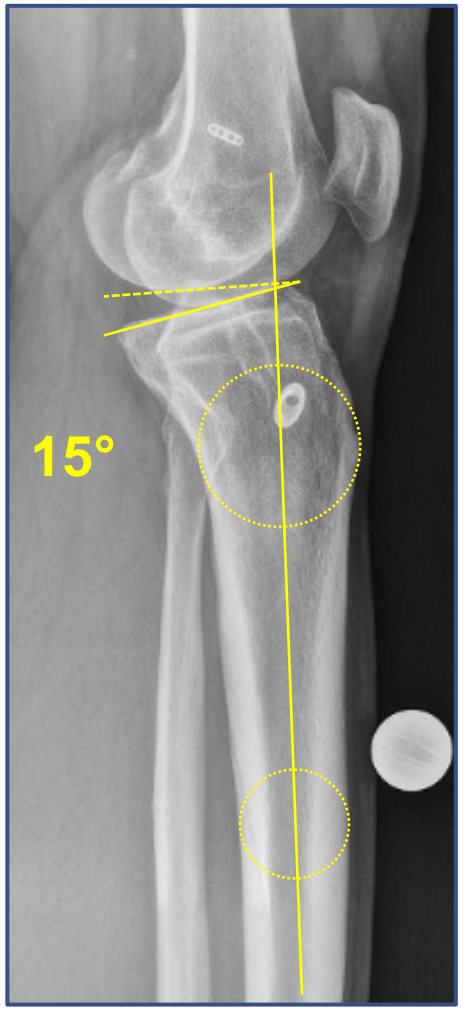
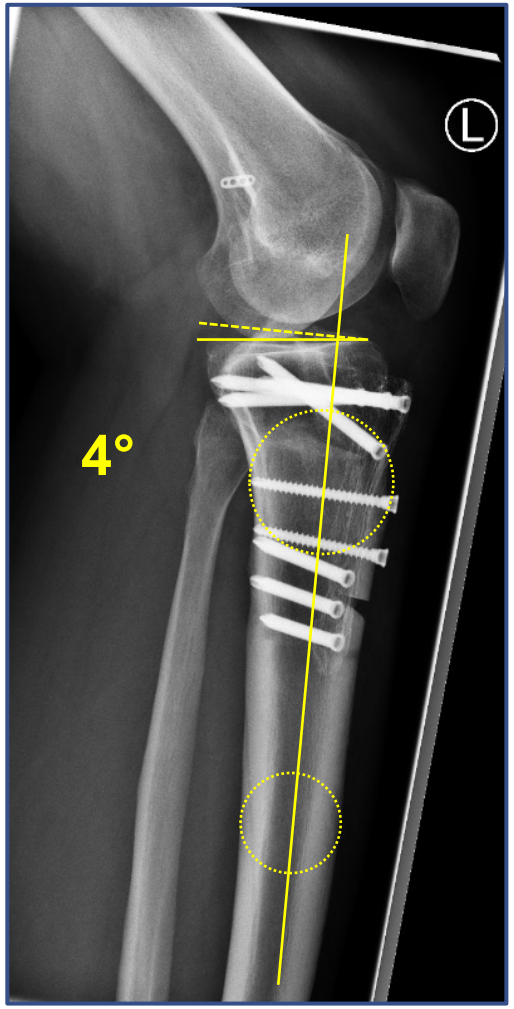
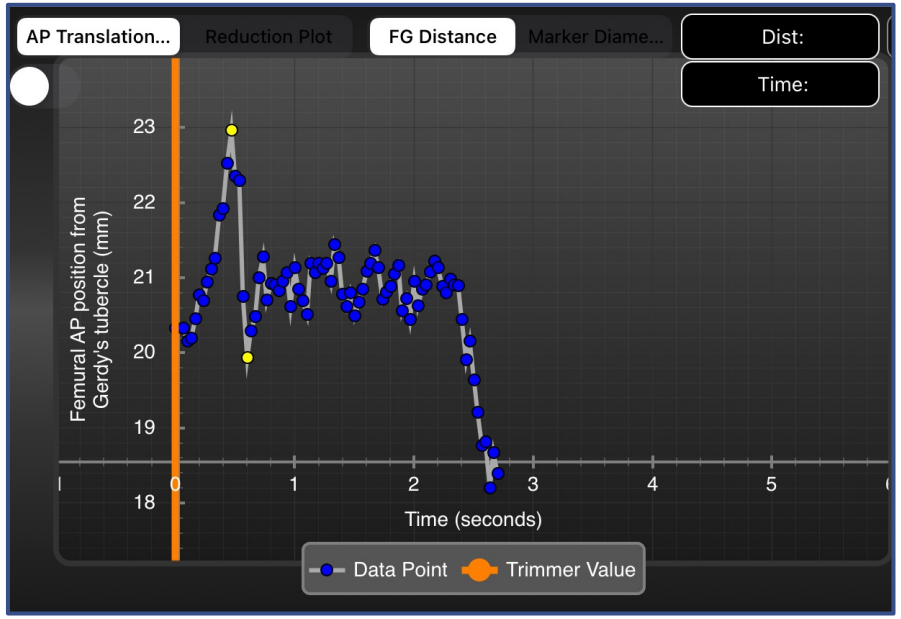


© Musahl, Winkler





Case II



Increased lateral tibial slope predicts high-grade rotatory knee laxity pre-operatively in ACL reconstruction

Ata A. Rahnemai-Azar[1,2] · Ermias S. Abebe[1] · Paul Johnson[1] · Joseph Labrum[1] · Freddie H. Fu[1] · James J. Irrgang[1] · Kristian Samuelsson[3] · Volker Musahl[1,2]

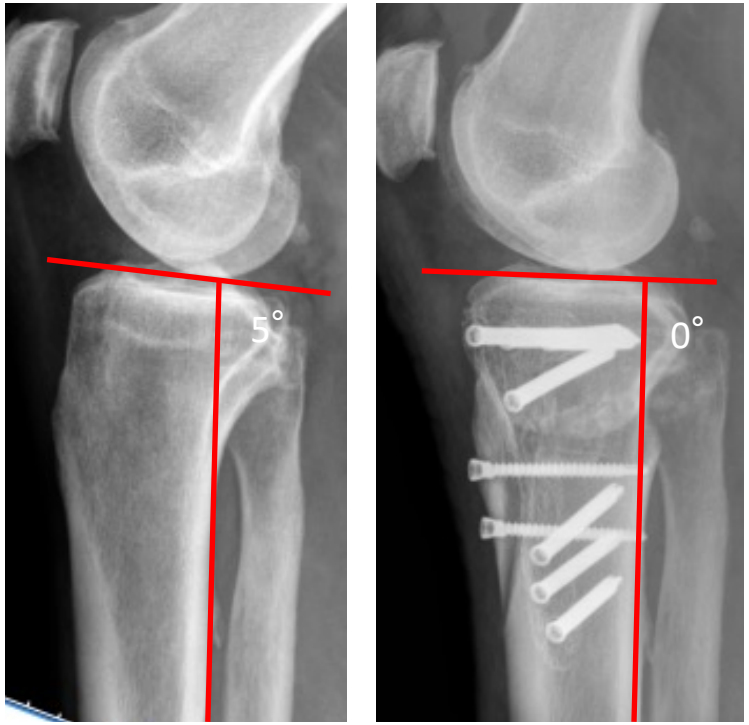
KSSTA. 2016.

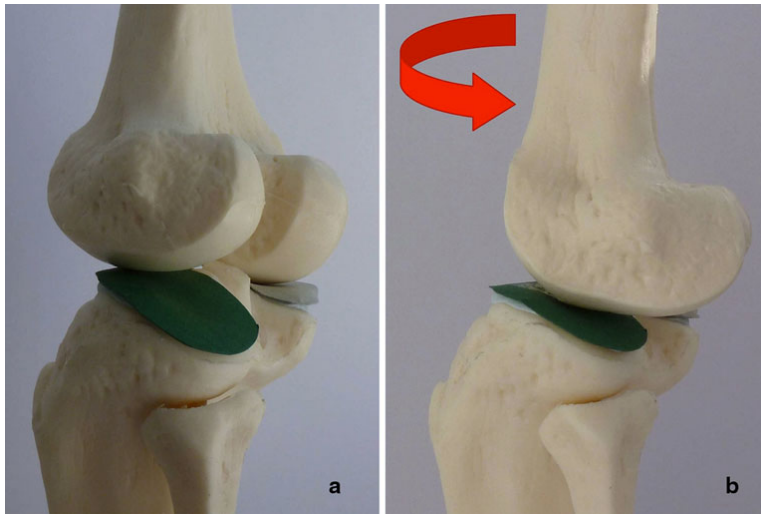
“Explosive” pivot-shift
+
High tibial slope

Purely ligamentous stabilization insufficient

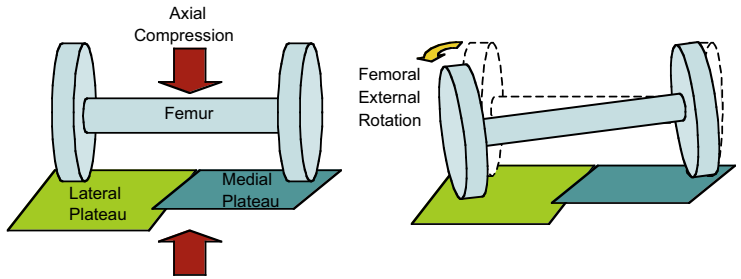
Case – Male, 46 y

HTO (55%) with 5° slope reduction without ACL-R





Slope and tibiofemoral rotation has to be considered!



Take Home

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Slope-reducing tibial osteotomy decreases ACL-graft forces and anterior tibial translation under axial load

Florian B. Imhoff[1,2] · Julian Mehl[1,2] · Brendan J. Comer[2] · Elifho Obopilwe[2] · Mark P. Cote[2] · Matthias J. Feucht[1] · James D. Wylie[2,3] · Andreas B. Imhoff[1] · Robert A. Arciero[2] · Knut Beitzel[1,2]

- Posterior tibial slope should be considered in ACL-R
- Correct if ligamentous stabilization is insufficient
- Technique depends on surgeon's preference

- "Slope-reducing osteotomy decreased anterior tibial translation in the ACL-deficient and ACL-reconstructed knee under axial load"
- "Especially in ACL revision surgery, the osteotomy protects the reconstructed ACL with significantly lower forces on the graft under axial load"

Slope-Reducing Osteotomy – Indications

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- Posterior tibial slope ≥ 12°

Webb et al. AJSM. 2013.

- Revision / multiple revision ACL-R
- Concomitant rotatory knee instability

Contraindications

- Preoperative knee hyperextension > 10°
- PCL insufficiency
- High-grade OA
- BMI > 30 kg/m^2
- Smoker

Vadhera et al. Curr Rev Musculoskelet Med. 2021.

Widely unknown – more evidence needed

Imhoff · Feucht *Eds.*

Surgical Atlas of Sports Orthopaedics and Sports Traumatology

Surgical Atlas of Sports Orthopaedics and Sports Traumatology

Andreas B. Imhoff
Matthias Feucht
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